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America's First Air Superiority Fighter

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US Air Force/SSgt David Nolan
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FOREWORD

F-15 Eagle: America's Air Superiority Fighter

Born and raised as a McDonnell Douglas jet in the early 1970s, the F-15 Eagle is the world's greatest post-war fighter aircraft with a kill tally of over 100 for no losses.

In the late 1970s, a US Air Force requirement for a tactical strike aircraft resulted in the F-15E Strike Eagle. Designed as a multi-role aircraft, like its F-15 Eagle sister ship, the F-15E is also proven in combat, and remains the US Air Force's tactical strike aircraft of choice, one with a lethal air-to-air capability and bucketloads of performance.

When McDonnell Douglas merged with Boeing in August 1997, the F-15 became a Boeing branded aircraft - a time when Boeing was only building variants of the Strike Eagle. Orders were thin on the ground, and in 2001, no F-15 deliveries were made. It was the only dud year in the programme's 48-year history. International orders for variants of the F-15 Advanced Eagle turned the programme's fortune around. Deliveries continued to Singapore, the Republic of South Korea, and Saudi Arabia.

This special publication provides details of the history, heroics and honourable service career of the McDonnell Douglas F-15 Eagle, and the very latest types entering service around the world. We also cover selected F-15 operators, pilot and weapon system officer training, recent operations undertaken by the 48th Fighter Wing based at RAF Lakenheath, England, and the all-new US Air Force F-15EX Eagle II.

Whether you're an avid aviation enthusiast or somebody with a general interest in great fighters, we hope you enjoy this homage to an amazing aircraft.

Mark Ayton
Editor

Dan Stijovich

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Origins of the EAGLE

In November 1974, **Jacob Neufeld** of the Office of Air Force History published an official internal study titled the *F-15 Eagle - Origins and Development 1964 - 1972.* The report provided details of how the type was conceived and developed. Declassified and approved for public release in 2008, **Mark Ayton** provides an edited version.

Abstract

This study traces the evolution of the F-15 Eagle air superiority fighter from its beginning in 1964 through the aircraft's first flight in July 1972. It examines the military, technological, economic, and political influences on the weapon system acquisition process. Among the more innovative elements of this research and development program were the energy manoeuvrability theory of Colonel John Boyd and Thomas Christie; a contractual arrangement loosely billed as the 'fly-before-buy' philosophy; and the definite Air Force commitment to building the aircraft first manifest in the appointment of Brigadier General Roger Rhodarmer as Washington F-15 spokesman, then through the support given by Major General Benjamin Bellis the F-15's strong program director. The story ends with air superiority reaffirmed as a major mission, but not yet fully defined.

The Air Superiority Mission

The roots of air superiority stem from the battlefields of World War Two. In 1939 and 1940 the German Stuka-Panzer drive across Poland, France, and the Lowlands stunned the world with its demonstration of the striking power of tactical air support.

Influenced by the German example, the United States War Department Field Manual 31-35, Aviation in Support of Ground Forces, April 9, 1942, allocated

aircraft resources to ground units and placed pursuit aviation under army control. It specifically prescribed that airpower's mission was to attack "the most serious threat to the operations of the supported ground force." This doctrine's first combat test came during the North African campaign in the winter of 1942. Components of the Twelfth Air Force under Second Corps provided air patrol, reconnaissance, and ground support of troop landings at Casablanca and Oran. Although air power helped a few ground units to move forward, its use to achieve the immediate objectives of the ground commander failed to accelerate the progress of the overall force. More importantly, it neither stopped German air attacks nor exploited such major objectives as enemy airfields and logistics.

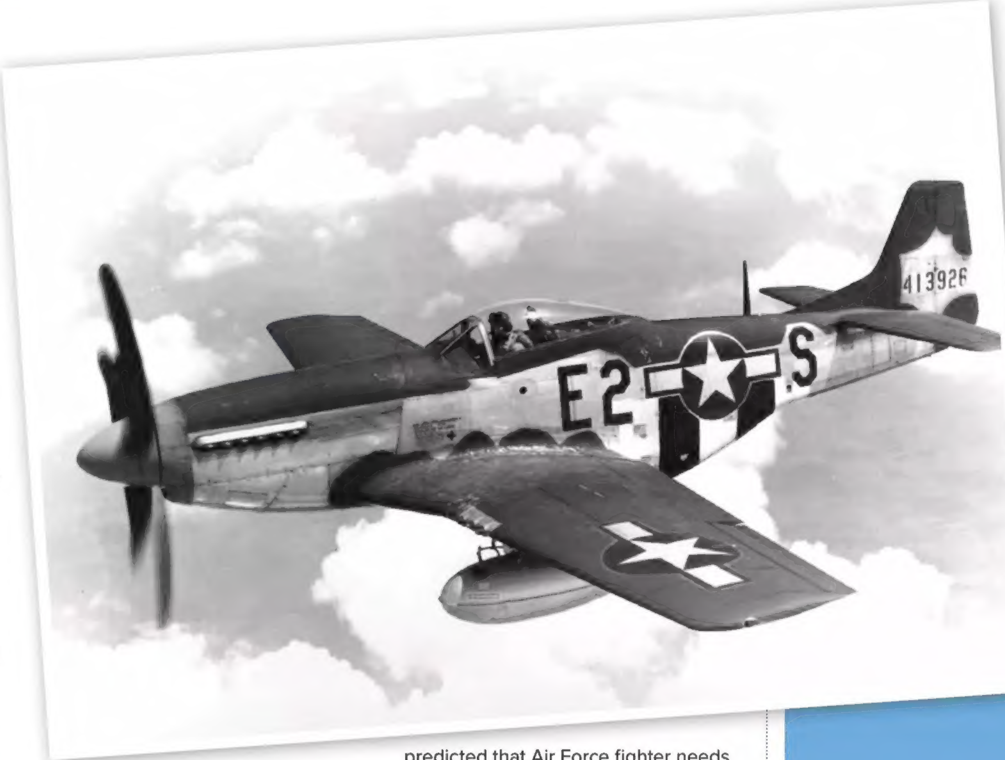
As a result of these experiences, US officials attending the Casablanca Conference in January 1943 adopted a new concept on the use of air power. Modelled after the Royal Air Force's support of the British Eighth Army in the Western Desert, the new arrangement centralised air resources under an air commander. The Allies then formed the joint American and British Northwest African Air Forces, which made possible the successful Allied drive from El Alamein to Tunisia. The new doctrine, formalised by Field Manual 100-20, Command and Employment of Air Power, July 21, 1943, set the pattern for the remainder of the war. It made land power and air power "coequal and interdependent forces; neither [was]... an auxiliary of the other." Moreover, it ranked "the gaining of air superiority... the first requirement for the success of any major land operation," placing this function ahead of tactical air's interdiction and close air support missions. Under this doctrine, the Allied Command's heavy bombing of enemy airfields, supplies, and communications was consistently successful. For example, in September 1943, prior to the Allied invasion of Sicily, tactical bombing and strafing destroyed more than half the once numerically superior Axis air force. Gaining and maintaining air superiority smoothed the way for the land invasion and prompted Field Marshall Kesselring, the German air commander in Italy, to describe the effort as "the most effective large-scale air force employment I have ever seen."

World War Two tested another theory of air power. American planners had entered the war convinced of the supremacy of the bomber. Its potential to strike decisively against an opponent's "sustaining sources of military strength" appeared to them as simply a matter of intelligent target selection and precision bombing. They completely discounted the possibility of tactical air interfering with or deterring bombing runs. The Battle of Britain, from July 10 to October 31, 1940, demonstrated the vulnerability of German bombers to a determined and well-executed RAF fighter defence. Rejecting British advice to conduct night operations, in 1943 the Army Air Forces (AAF) launched daylight bombing raids into Germany which were initially handicapped by a shortage of aircraft, the limited range of fighter escorts, and bad weather over the European continent. Above all, the 'sting' of German fighters prevented effective results. American bombing missions against Schweinfurt, Regensburg, Kiel, and other German targets incurred heavy losses - some as high as 50%.

Following the second Schweinfurt raid in October 1943, the AAF halted unescorted bomber penetrations. To provide long-range fighter escort, it adapted external fuel tanks, originally designed for ferrying operations, for use on fighters. The range of the P-47, for example, was extended from 175 to 400 miles. But it was not until after the arrival of the P-51 at the end of 1943 that the Eighth Air Force had a superior, highly manoeuvrable fighter which could escort bombers to almost any target in Germany. A later change in the mission of a portion of the P-51 force also had far-reaching effects. While one-third of the growing inventory of fighters provided close escort for bombers, the remaining two-thirds made offensive sweeps 'pursuing and destroying' enemy fighters wherever they were found. The air campaign between February and May 1944 established Allied air superiority to the point that by D-Day General Eisenhower could assure the Normandy invasion force, "If you see fighter aircraft over you, they will be ours."

The cost of achieving and maintaining air superiority was high. Prior to June 1944, the AAF lost 325 aircraft, 17,000 crewmen, and another 21,000 missing or captured. Bombers as well as fighters fought the battle for air superiority, with a major portion of the B-17 strikes being launched against German aircraft plants, oil refineries, and airfields. From D-Day

BELOW: *Image by Paul Ridgway*



through the end of the war, 320,000 sorties, or 25% of the total, involved air superiority. The post-war US Strategic Bombing Survey (USSBS) measured air power's accomplishments...by the extent to which they contributed to the destruction of the enemy's military strength... [but] of far more significance than statistics of strength and damage is the outstanding fact that the Allied air forces won the air war over Germany and obtained mastery of the skies in Europe.

During the Korean War, commanders applied the tactical air lessons learned in World War Two with only minor changes. Again, priority was given to winning air superiority. However, a major difference between the two wars was that in Korea the air battle proved 'short and sweet'. During the first two months of Korean operations, the United States Far East Forces (FEAF) achieved air superiority over a small and relatively weak opponent. Attacked on the ground and in the air, the North Korean Air Force lost 110 of its 132 aircraft by mid-August 1950.

The second phase of the air superiority contest began in November 1950, when the Communist Chinese MiG-15 fighters suddenly appeared in the skies over North Korea. Because political restrictions barred attacks on Chinese bases north of the Yalu River, the Air Force concentrated on destroying all enemy airfields in North Korea. Accordingly, FEAF bombers and fighters continually struck these airfields to keep them inoperative. Meanwhile, FEAF deployed F-86 Sabre jet fighters to challenge the MiG-15s in air combat. Although the two aircraft were evenly matched, the more experienced and better trained American pilots proved superior in dogfights. Patrolling and engaging the enemy fighters in 'MiG Alley' over the Yalu, the Sabres relentlessly whittled down Communist air strength during 1951 and 1952.

Though the enemy Air Force was never totally eliminated, the 10-1 kill ratio in air combat permitted FEAF to maintain air superiority throughout the Korean War.

Following the Korean War, President Dwight D. Eisenhower adopted a policy of nuclear deterrence that relied primarily on the strategic air force and downgraded the conventional war mission of tactical fighter aircraft. For example, the Century series fighters (F-100 through F-111) were increasingly designed for use against strategic targets in nuclear war rather than for tactical air combat. Although air superiority remained the 'prerequisite' for conducting any air operation, General Bruce Holloway, the Air Force vice chief, wrote in 1968 that plans to develop a new day fighter were continually sacrificed in favour of interceptor and fighter-bomber designs: "Penetration was more important than manoeuvrability, ordnance load-carrying capability more important than armament, alert status more important than sustained sortie rates. The tactical fighter became less and less an air superiority system and more and more what was once called an attack aircraft."

Indeed, jet fighter-bombers had performed so well in Korea that a 1957 study rated them 'just as capable in aerial combat as the day fighter'.

Forgetting the political and geographic limitations that shackled FEAF in Korea, the Air Force continued to promote the most expeditious means of gaining air superiority: "to first destroy the enemy air forces at the place where he is most vulnerable, which is on the ground and in his nest." Major General A. J. Kinney, assistant deputy chief of staff for research and development summarised this basic strategy: "To achieve air superiority, the most lucrative method is to destroy enemy air capability when it is on the ground by attacking his airfields and parked aircraft. Runways are bombed to prevent take-offs, airplanes are destroyed before they can be employed; fuel and ammunition dumps, maintenance facilities and command and control centres are attacked."

Project Forecast, a 1963 Air Force attempt to identify future weapons requirements, had foreseen such notable developments as the C-5 and B-1 programs. Directed by General Bernard Schriever, commander, Air Force Systems Command (AFSC), Project Forecast proved less clairvoyant regarding the future of fighters. It predicted that Air Force fighter needs in the 1970s would be met best by F-111 and F-4 variants "optimized for the air superiority role," and that strategic bombing from aircraft able to fly faster and higher than the enemy's, would insure air superiority. Almost as an afterthought, Project Forecast added that "the counterair force must be able to destroy aircraft in the air..."

The Requirements Phase

Upon becoming Air Staff director of plans on July 1, 1964, Major General Arthur Agan found a great many Pentagon officials believed that the dogfight and aerial guns were relics of the romantic past and that missiles would dominate future air battles. This certainly was the view of army members of the Joint Staff, whose situation had greatly improved vis-à-vis the Air Force under the Kennedy administration. For example, Lieutenant General Theodore Parker, army deputy chief of staff for military operations, had questioned the effectiveness of all tactical fighter aircraft for gaining air superiority and for interdiction in future conventional wars. Parker argued that the growing advantages of surface-to-air missiles (SAMs) would shortly become clear and would impose unacceptable losses on fighter aircraft.

General Agan disagreed. As a former World War Two P-38 pilot and group commander who flew 45 combat missions over Europe, he was convinced that high performance fighter aircraft would survive and remain the key to successful ground operations. Unfortunately, since the Office of the Secretary of Defense (OSD) had authorised the Air Force to acquire two

LEFT: **North American P-51D Mustang 44-13926 over France. During World War Two, P-51s destroyed 4,950 enemy aircraft in the air, more than any other fighter in Europe.** *US Air Force*

BELOW: **P-47 Thunderbolt 45-49192 and Spitfire VC EE602 at RAF Lakenheath, England during a Heritage fund raising event on May 7, 2018. The Thunderbolt was painted to replicate the F-15E Strike Eagle-equipped 492nd Fighter Squadron's World War Two colour scheme.** *US Air Force/Airman 1st Class Christopher Sparks*

new multipurpose fighters - the F-4C and the F-111 - General Curtis LeMay, Air Force chief of staff, and Secretary of the Air Force Eugene Zuckert were in no position to ask for development of still another fighter.

In meetings with Dr Alain Enthoven, Assistant Secretary of Defense for Systems Analysis, General Agan learned that OSD favoured purchase of large numbers of small, inexpensive attack aircraft for the tactical air forces. Enthoven and other members of Secretary McNamara' s systems analysis staff thought in terms of measuring the effectiveness of the three primary tactical air missions - air superiority, close air support, and interdiction - "by their impact on the force ratio between opposing land forces, and thus... the land/air 'trade-off' would be a decisive factor in sizing US tactical air forces."

While General Agan and the Air Staff were not particularly opposed to this cost effectiveness approach, they felt it ignored the essential point - that in wartime little could be done without first achieving air superiority and that one of OSD's highest priorities should be to ensure the United States acquired the best possible fighters in the world.

Like most members of the Air Staff since the McNamara era dawned, General Agan found Enthoven and other members of the OSD staff hostile to Air Force views. Thus, whereas during the 1950s, President Dwight D. Eisenhower's policy of strategic deterrence had made the US Air Force the dominant service, under President Kennedy the army achieved the stronger position. The president adopted the concept of "flexible response," which had been advocated in the late 1950s by General Maxwell Taylor, the former army chief of staff. In 1961, President Kennedy brought General Taylor back to active duty, first as his special military representative and later as chairman of the Joint Chiefs of Staff (JCS).

Frustrated by OSD's cost-effectiveness approach, General Agan determined to find some way to articulate his strong feelings about air superiority. Thus, in the fall of 1964 he commissioned a prestigious committee of fighter aces and other experienced fighter pilots to examine the Air Force's tactical air capabilities. He hoped this group might provide the leverage needed to begin development of an aerial gun for the F-4C and help launch a new air superiority fighter program. Chaired by Brigadier General Harrison Thyng, the group included Colonels Francis Gabreski, William Dunham, Winston Marshall, George Laven, Jack Holly, and John Burns. Predictably, the group concluded there was an urgent need to develop a new fighter to offset the growing Soviet capability in this area. However, well aware of the Air Force's sensitivity to any challenge to the decision to acquire the F-111, the Thyng committee merely

recommended more study of a new fighter development programme. OSD received a copy of the committee report but took no action.

Although General Agan failed to convert OSD officials, he did manage to persuade LeMay's successor, General John McConnell (he became chief of staff on February 1, 1965), of the need for a new fighter. Backed by McConnell, Agan drafted a statement on tactical air superiority that the former endorsed and circulated Air Force-wide. The policy statement, issued in May 1965-after combat operations over North Vietnam had begun - recognised ...the Air Force's requirement "to win air superiority."

Another individual who helped promote the air superiority mission was a former US Navy flier and experienced test pilot, Charles Myers. In 1963 and 1964 Myers was working for Lockheed Aircraft trying to sell F-104s to the services. During the course of his visits with US Air Force and Navy officials he became acquainted with several aspects of aerial combat that no one appeared to have previously addressed. In discussing the subject with pilots of both services, he learned that most aerial combat was confined to a spatial area or flight envelope between sea level and 30,000 feet, was conducted at speeds up to Mach 1.6, and that air-to-air missiles had severe limitations. For example, an F-4 pilot first had to close with his target for positive enemy identification and then drop back far enough to launch his Sparrow missile effectively. Myers developed a considerable following in the services lecturing on these facts, although he came to realise that the F-104 was not saleable. Subsequently, he formed a private consulting firm but continued to push air superiority.

The War's Impact

OSD interest in acquiring new fighters did not surface until it became clear that the existing USAF aircraft being used to provide close air support for South Vietnamese troops were obsolete and dangerous. For example, in March and April 1964, two Air Force T-28 close air support aircraft crashed when their wings sheared off during bomb runs, killing all crew members. Wing failures discovered in RB-26 strike aircraft also led to their grounding. In response to this situation, in December 1964, Secretary Zuckert requested $50m to modernise and expand the USAF's Special Air Warfare (SAW) strike and reconnaissance force. On January 7, 1965 Mr McNamara responded by allotting only $10 million in FY1966 funds for Air Force modification of existing tactical aircraft. At the same time, he directed the Air Force to consider developing a new fighter "optimized for close support and useful in ground attack" and to assume tactical air superiority in their planning for Vietnam.

Secretary Zuckert and Air Staff officials were disturbed by McNamara' s instructions that they 'assume' tactical air superiority in their planning. In a reply on February 2, 1965, Zuckert reported that the Air Force could not define a new tactical fighter without first assessing its effect on the tactical force structure. At the time of his reply, the Air Staff had been working

"The cost of achieving and maintaining air superiority during World War Two was high. Prior to June 1944, the AAF lost 325 aircraft, 17,000 crewmen, and another 21,000 missing or captured. "

since August 1964 on a study titled 'Force Options for Tactical Air'. Named after its chairman, Lieutenant Colonel John Bohn, Jr, it critically assessed the Air Force's reliance on high-performance tactical fighters to provide "the greatest flexibility at the lowest cost." Because it found that aircraft like the F-111 were far too costly to be risked in non-nuclear war, the study sparked interest in lightweight, lower cost specialised aircraft. Using both manual and computer analyses, the Bohn group surveyed several kinds of aircraft, including stripped versions of the A-1E, F-4, A-6, F-104, and vertical or short take-off and landing aircraft. It subsequently rejected all these alternatives, branding the cheaper versions of high-performance aircraft as 'non-cost effective' and declaring that the others did not meet desired performance requirements.

Completed on February 27, 1965, the Bohn study recommended the Air Force acquire a mix of high- and low-cost aircraft as the most economical way to strengthen the tactical force. For the support role, the study narrowed the candidates to the lightweight, comparatively inexpensive Air Force F-5 and the Navy's A-7. Both seemed equally attractive: The A-7 could carry a greater payload, whereas the F-5 was considered superior because of its air-to-air combat capability. General McConnell was briefed on the study on March 9 and Secretary Zuckert and his staff two days later. McConnell subsequently advised Zuckert that the Bohn study showed the folly of assuming air superiority and, in support of this view, he cited recent Defense Intelligence Agency estimates that new Soviet interceptors posed a threat beyond the capability of existing US forces to counter. He argued that air superiority involved the ability of fighter aircraft to survive attacks both by enemy interceptors and anti-aircraft (AA) weapons. As evidence of the latter, he could cite the March 2, 1965 downing of three USAF F-105s and two F-100s over North Vietnam by enemy ground fire. As for the close air support mission itself, he proposed bringing a

LEFT: ***A P-47 Thunderbolt photographed in late 1943 when assigned to the 325th Fighter Group fitted with underwing fuel tanks.*** *US Air Force*

BELOW: ***North American F-51D 44-84778 parked on the flight line somewhere in Korea. The pilot is shown walking towards the aircraft, his helmet sits on the left wing. A crewman stands on the right wing beside the cockpit, and another bends down beside the left wheel.*** *US National Archives*

mix of lower-cost aircraft into the Air Force inventory.

Although Secretary Zuckert backed McConnell, he warned that outsiders would view the Air Force recommendation as an attempt to expand its force structure by beefing up its SAW resources. Nevertheless, on March 16, Zuckert forwarded the Bohn study to OSD and recommended the Air Force be authorised to purchase two wings of F-5s as an interim measure while beginning work on a medium cost tactical fighter for the 1970s. He amplified his position in April, when he described the proposed new fighter to McNamara as one which also would have "significant air-to-air fighting capability."

Meanwhile, another Air Staff study on 'Tactical Fighter Ground Attack Aircraft' had begun under the direction of Colonel Bruce Hinton. Completed in June 1965, this study concluded that the A-7 would be the best close support aircraft if the Air Force could assume air superiority. However, Hinton's group questioned that assumption and recommended the Air Force select the F-5. It noted that acquisition costs of the F-5 could be recouped through the Military Assistance Program since the basic version of the fighter was intended for sale to America's allies.

Aware of Air Staff disagreement about the A-7 vs the F-5, and noting OSD's indecision on the matter, Secretary Zuckert decided not to press for the latter until the Air Force had crystalized its position on tactical forces. Another important reason for the delay was to enable the Air Staff to undertake a detailed examination of another option, the proposed medium-cost F-X (fighter experimental).

The F-X Working Group

In April 1965, Lieutenant General James Ferguson, deputy chief of staff for R&D won the support of Dr Harold Brown, director of defense research and engineering (DDR&E) for the official Air Force position. That is, Dr Brown agreed to the interim acquisition of the F-5 (an improved version and not the model intended for export) and authorised development of an F-X. Thereupon, General Ferguson established an Air Staff work group under Brigadier General Andrew Evans Jr, director of development, and Dr Charles Christenson, science advisor to the R&D department. The group conducted prerequisite studies for an F-X to cost between \$1-2m each, with a production run of 800 to 1,000 aircraft. The contemplated fighter would possess 'superior air-to-air, all-weather, and aided-visual-ground attack' capabilities. It also was envisioned as a single-seat, twin-engine fighter stressing manoeuvrability over speed. The F-X initial operational capability (IOC) was 1970.

The F-X group, recognising early it

needed help to produce worthwhile studies, began seeking funds to contract out the effort. DDR&E representatives told the group it could obtain study funds if the F-X were presented as a multi-purpose fighter... whereas any attempt to point it, in the direction of a specialised combat plane would fail. Supporters of an air superiority fighter, including Generals Ferguson and Jack Catton, director of operational requirements, found this view was shared by elements of the Air Staff. They therefore decided to disguise the F-X as a multipurpose fighter and advertised air-to-ground capability ahead of air-to-air. By July 1965, program element 6.34.06.84.4, 'Close Support Fighter', emerged as the logical source for obtaining study funds and on August 12, the Air Force requested $1m for parametric design studies for the F-X under the Close Support Fighter funding line.

Meanwhile, Air Force complacency over tactical air superiority began evaporating after two F-105s were shot down on April 4, 1965 by several supposedly obsolete MiG-15s while on a bomb run near Thanh Hoa, North Vietnam. Since the F-105s were laden with ordnance, the contest was not an equal one. The Air Force's response was to immediately dispatch F-4Cs to the theatre to fly cover for the fighter-bombers. The episode rekindled interest in tactical air superiority, lent added urgency to the F-X effort, and prompted General Ferguson to seek cooperation from the field. On April 29, using the same guidelines established for the Air Staff's concurrent F-X studies, he directed the Air Force Systems Command to undertake studies at the Aeronautical Systems Division (ASD) of a multi-purpose fighter with a short take-off and landing (STOL) capability.

The requirement for a STOL fighter attracted the attention of Colonel John Burns, assistant director of requirements, headquarters, Tactical Air Command (TAC). Colonel Burns, who had been a member of the Bohn study group and the Thyng committee and was an ardent air superiority advocate, pounced on the STOL requirement and immediately drafted a position paper for an air superiority fighter. Though General Walter Sweeney, the TAC commander, was sympathetic to the proposal, Colonel Burns was unable to convince him to issue a formal requirement for a light-weight day fighter. General Sweeney's upcoming retirement and poor health may explain in part the temporary shelving of the proposal.

However, TAC did convene a select panel of field commanders in June 1965 to consider the projected Soviet tactical fighter threat. In a departure from concepts pursued in USAF tactical fighter development over recent years, the TAC commander's panel expressed a clear preference for a lightweight day fighter. Their model was a single-seat, twin-engine aircraft in the 20,000 to 25,000-pound class. Though asking for an aircraft that could fly from Mach 1. 2 on the deck up to Mach 2.5, the panel stressed manoeuvrability more than speed. The panel's report was not distributed; however, its conclusions - which closely paralleled Colonel Burns' views on air superiority - served as a kind of framework for the TAC position.

When on August 1, 1965 General

Gabriel Disosway - a World War Two fighter pilot commander - took over TAC, he immediately reviewed Colonel Burns' work and wasted little time in issuing Qualitative Operation Requirement (QOR) 65-14-F on October 6. The document, sent to the Air Staff, emphasised TAC's interest in an "aircraft capable of out-performing the enemy in the air." Besides challenging the notion that only a multi-purpose fighter could gain OSD and Congressional approval and bringing the controversy into the open, it specified an aircraft like the one described by the June 1965 TAC panel, except that it raised the plane's weight to a 30,000-35,000-pound range. The requirement also called for providing the new aircraft with a radar capability similar to the F-4's and that it needed to be equipped with both infrared and radar missiles. TAC also emphasised the need for manoeuvring performance and high thrust to-weight ratio but for temperature limitation, it lowered the maximum speed requirement from Mach 3.0 to Mach 2.5 - a change that would save between 35 and 40 percent of the total cost, or $4.5m versus $2.5m per aircraft.

The Pivotal Decision

During the summer and fall of 1965, the Air Force continued to wrestle with the F-5 versus the A-7 issue. OSD, particularly Systems Analysis, was still enamoured of the 'commonality' principle wherein the Air Force and Navy would possess a combined tactical force comprised of F-111, F-4, and A-7 aircraft. In July, Secretary McNamara directed OSD and the Air Force to begin a joint study to select either the F-5 or A-7 for the close air support role in Vietnam. At the same time, but on a lower priority, he endorsed the Air Force's prerequisite work on developing the new F-X fighter. Meanwhile, Dr Brown - who as DDR&E had backed the F-5 - reversed his position after being named secretary of the Air Force, a position he assumed on October 1. On November 5, he and General McConnell proposed acquiring 11 squadrons (264 aircraft) of A-7s. Although criticised in some Air Force circles as a capitulation to OSD, the decision to buy the A-7 was in fact a sensible compromise that ultimately gained approval for the F-X. General Agan recognised this point and endorsed the decision. The F-X could now be justified as a 'more sophisticated, higher performance aircraft... an air superiority replacement for the F-4'.

General Agan later described the various kinds of aircraft the Air Force needed to fight in various conflicts. He wrote that the Air Force believed that "the basic F-111A and F-4 inventory of the future must contain other aircraft. The views of the characteristics which these aircraft should have vary widely. By study, by wargaming, and by testing we hope to arrive at an answer. My own belief is that a smaller aircraft than the F-111, and possibly than the F-4, is needed - and needed now. It can be smaller because we can plan to use it for air superiority and close air support and thus can accept less range and payload in order to get superior agility. We can accept less range because the majority of the targets which we expect in close air support will be within 250 miles of the forward edge of the battle area. We can accept less payload because of improved ordnance and more accurate delivery of weapons. Such an aircraft may be able to win the

US Air Force/Airman 1st Class Christopher Sparks

air superiority fight over the battlefield. It should be a medium-cost aircraft because we will need many."

F-X work statements were revised to call for an aircraft with the 'best combination of air-to-air and air-to-ground characteristics' vis-à-vis the previous description of the development as aiming at medium-cost, multi-purpose aircraft, highlighting close air support. Although this change seemed mere semantics, it permitted the Air Force to launch a major effort to acquire a new fighter. Secretary Brown had opened the door to the F-X and, more importantly, he placed the emphasis on the air-to-air mission and the need to increase the size of the tactical force.

Meanwhile, TAC began to move after many years coming out second best in the internal struggle for resources with the 'monolithic, global commands such as MAC and SAC'. To restore some balance, General Disosway worked to bring to bear the influence of all major tactical air commanders. For example, he arranged periodic conferences with his counterparts in the United States Air Forces, Europe (USAFE) and the Pacific Air Forces (PACAF). Their joint position statements, aptly called the '12-star letters' (three four-star generals) - which they sent to General McConnell - were difficult to ignore. The first such conference held at TAC headquarters at Langley AFB, Virginia, in February 1966, produced several position statements on tactical air power. Signed by Generals Disosway, Holloway, and Hunter Harris, the letters significantly influenced the F-X requirement. The three commanders stated simply that air superiority would be severely jeopardised if the F-X were designed to accommodate both air-to-air and air-to-ground missions. Instead, they urged the chief of staff to endorse air superiority as the primary mission of the F-X, with secondary missions being considered a bonus from the aircraft's superior design.

General Disosway and his operations advisors, Colonels Burns and Gordon Graham, believed that air superiority was essential throughout the spectrum of tactical warfare. Given the limitations on the employment of tactical air power, such as the enemy sanctuaries that existed during the Korean and Vietnam Wars, an uncompromised fighter was needed to sweep the skies clear of enemy aircraft. They argued that the only way the Air Force could meet the challenge posed by lightweight, manoeuvrable Soviet fighters in the 1970s was to design a superior air combat fighter.

Although the 12-star letters received high-level consideration, Headquarters USAF decided to follow the path of least resistance - namely, to continue to study, justify, and document the case for a fighter capable of handling both the air superiority and ground attack missions.

General Ferguson, who became commander of the Air Force Systems Command (AFSC) in September 1966, responded to TAC by asking General Disosway to await the results of parametric design studies that began in March 1966. Ferguson personally opposed the parametric study requirement but believed the results would substantiate the case for an air superiority fighter. Six types of aircraft. including two 'families' of low, medium, and high-cost fighters (costing $1.8m, $2.5m and $3.2m respectively) were studied. One family of fighters studied emphasised air combat capability with ground attack being a secondary requirement. whereas the second examined the effect of reversing the mission order.

Concept Formulation Phase

On December 8, 1965, the Air Force sent requests for proposals (RFPs) to 13 aircraft manufacturers for the initial F-X parametric design studies. After receiving bids from eight companies, on March 18, 1966, the Air Force awarded study contracts to Boeing, Lockheed, and North American. A fourth firm, Grumman, participated in the study effort on an unfunded basis. After considering the effects of five variables - avionics, manoeuvrability, payload, combat radius and speed - on the F-X in terms of weight and cost, the contractors came up with some 500 proposed designs. In July, after examining these designs,

BELOW: ***The unmistakeable fuselage line of a P-51 Mustang.*** *US Air Force/Senior Airman Kathryn Reaves*

RIGHT: ***Two F-86 Sabres fly together during the Heritage Flight Training and Certification Course at Davis-Monthan Air Force Base, Arizona, on February 12, 2017. The first production model of the F-86 flew in 1948 and supported the Strategic Air Command from 1949 to 1950.*** *US Air Force/Senior Airman Chris Drzazgowski*

the Aeronautical Systems Division (ASD) selected what it believed was the best one for an air-to-air and air-to-ground aircraft.

Indeed, the emphasis on the multi-purpose features of the F-X dominated ASD's parametric studies. The division's goal was to develop an aircraft with sufficient performance capability to offset the alleged Soviet superiority in manoeuvrability while maintaining the continued US edge over Russian planes in range. To accommodate these multi-purpose requirements, the four study-contractors agreed that the F-X needed avionics comparable to the F-111's Mark II system. Moreover, they understood that multi-purpose meant the use of a variable sweep wing design for the F- X and that a high bypass-ratio turbofan engine seemed preferable to a low-bypass engine. As for armaments, they called for considerable air-to-ground ordnance including the 20mm M61 cannon with 1,000 rounds, four fuselage mounted missiles, and a 4,000-pound allowance to permit loading eight Mk82 bombs, or other munitions. Finally, the contractor designs favoured podded engines over fuselage mounting (to avoid the inlet distortion problems of the F-111) and placing the horizontal tail surfaces on the engine pods for increased area.

Some critics saw ASD's parametric F-X design as a typical case of 'gold plating'. They complained that the Aeronautical Systems Division, convinced that the F-X represented the 'one aircraft for the generation', had decided to advance aeronautical art by applying their 'wish lists' across several disciplines. Others, however, thought that while the ASD engineers had made a sincere attempt to provide the Air Force with the 'best aircraft possible', they had become 'victims of the system'. Regardless of these criticisms, what emerged was a proposed F-X weighing more than 60,000 pounds (to accommodate all the avionics and armaments packages). The aircraft would have a 110-pound per square foot wing loading, a thrust-to-weight ratio of 0.75, and a 2.2 bypass turbofan engine. Finally, the F-X would require extensive use of exotic new materials to attain a top speed of Mach 2.7. All told, ASD's Deputy for Advanced Systems Planning estimated that R&D costs for FY1967-1972 would be about $760m. The F-X, then, promised to be a very expensive aircraft resembling the F-111 but which, in no sense, would be an air superiority fighter.

Energy Manoeuvrability

General Ferguson and his development planners, Major General Glenn Kent and Brigadier General F. M. Rogers sensed that the F-X requirements were 'badly spelled out'. They subsequently were able to persuade General Disosway to modify his requirements, thanks in large part to the work of Major John Boyd. In October 1966, Boyd joined the Tactical Division of the Air Staff Directorate of Requirements. When asked to comment on the 'Representative F-X design', he summarily rejected it. A veteran pilot of the late 1950s and author of the air combat training manual used by the Fighter Weapons School at Nellis Air Force Base, Nevada, Boyd was well qualified to assess fighter aircraft. In 1962, while completing an engineering course at Georgia Tech, he studied the relationships between energy and energy changes of aircraft during flight and devised a method to measure aircraft manoeuvrability - the ability to change altitude, airspeed, and direction.

Major Boyd continued his energy manoeuvrability (EM) studies at his next station, Eglin Air Force Base, Florida, even though his primary assignment there was maintenance officer. At Eglin he met Thomas Christie, a mathematician who also saw promise in the EM theory and who had access to a large-capacity, high-speed computer. With Christie's help Major Boyd gained access to the computer to confirm his calculations. For this irregularity - working outside authorised channels - they were both severely criticised. However, with the help of Brigadier General Allman Culbertson, Air Proving Ground Center (APGC) vice commander, Boyd and Christie fought off repeated attempts to terminate their studies and in May 1964 published an official treatise on energy manoeuvrability.

Although the EM theory did not represent anything new in terms of physics or aerodynamics, it led Boyd and Christie to devise a revolutionary analytical technique that permitted fighter 'jocks' to communicate with engineers. The EM theory expressed in numbers what fighter pilots had been trying to say for years by moving their hands. It also permitted planners and developers to compare competing aircraft directly and to demonstrate the effects of design changes on aircraft performance. Finally, the theory could be used to teach pilots how to exploit their aircraft's advantages over that of the enemy.

During 1964, the EM theory was

informally brought to the attention of members of the Air Staff, including Generals Agan and Catton. Colonel Burns who made use of it in his studies beginning with the Thyng Committee study, assigned values to various elements of the EM theory, and established 'measures of merit' for comparing different aircraft designs in terms of manoeuvrability. Perhaps because the EM analytical technique was in its formative stages, it did not gain immediate acceptance.

Meanwhile, working within the Tactical Division, Major Boyd began to apply the EM theory to the F-X, projecting how the aircraft would perform in the critical manoeuvring performance envelope - the subsonic and transonic speeds up to Mach 1.6 and altitudes up to 30,000 feet. He then asked TAC, ASD, and the study contractors to provide trade-offs between range, structural requirements, and on-board equipment. Then, by comparing configuration changes for fixed and variable wing sweeps, Major Boyd designed a model that would demonstrate the effects of specific requirements on the F-X design. For example, he could show the manoeuvrability penalty that TAC would have to pay if it desired the F-X to have a given range.

By the spring of 1967, through the efforts of Boyd and others, a 40,000-pound F-X aircraft was 'popped out'. Its proposed engine bypass had been lowered to 1.5, thrust-to-weight increased to 0.97 and the F-X top speed scaled down to a range of Mach 2.3 to 2.5. During the various design trade-offs, Major Boyd challenged the validity of ASD's drag polars (lift versus drag charts) and argued that lower wing loadings on the order of 80 pounds/square feet would be more appropriate for the F-X design.

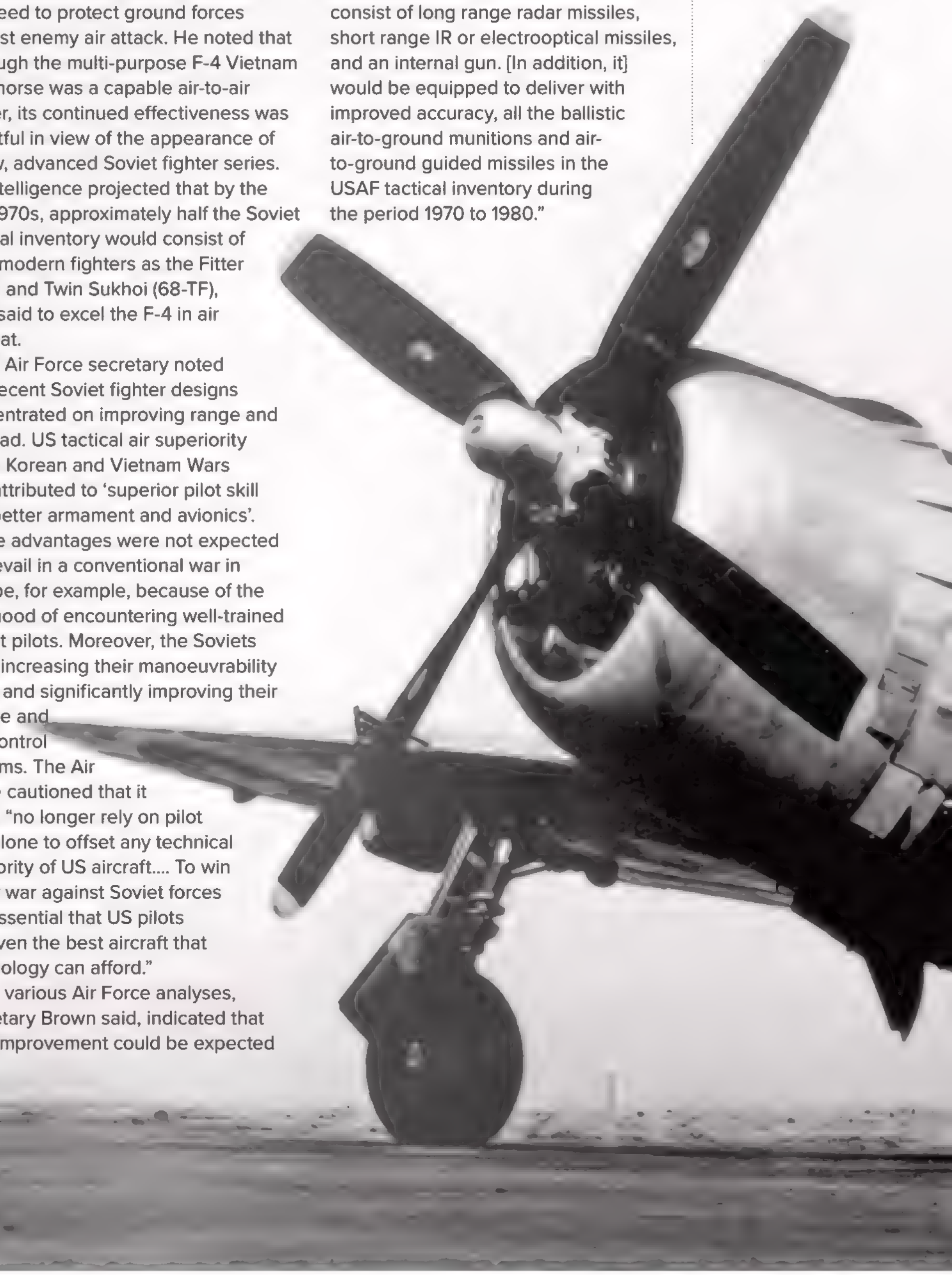
Doggedly pursuing his research into drag polars, he later examined the effects of optimising propulsion, configuration, avionics, and weapons for the fixed and variable sweep-wing designs. His calculations of these trade-offs pointed to 0.6 as 'the best' engine bypass ratio and to a 60 to 65 pounds/square feet wing loading. The design studies incorporated into the final F-15 configuration confirmed these values.

Concept Formulation

The F-X formulation phase continued through the spring and summer of 1967. By March, a three-part Concept Formulation Package (CFP) and a Technical Development Plan (TDP) were drafted to specify the F-X rationale, cost, and development schedule. In June, a complete CFP was issued, and it underwent a final Air Staff-ANSER 'massaging' by August 1967. Secretary Brown then submitted the revised cost proposal to OSD as the Air Force's recommended new tactical fighter candidate to replace the F-4. He noted the Air Force's tactical force structure for the mid-1970s limited to 24 wings by OSD - included 13 F-4, 6 F-111 and 5 A-7 wings that were respectively oriented to perform counter air interdiction, and close air support missions. Secretary Brown now argued for the paramountcy of counterair (air superiority), without which the other missions would be either too costly or impossible, and the need to protect ground forces against enemy air attack. He noted that although the multi-purpose F-4 Vietnam workhorse was a capable air-to-air fighter, its continued effectiveness was doubtful in view of the appearance of a new, advanced Soviet fighter series. US intelligence projected that by the mid-1970s, approximately half the Soviet tactical inventory would consist of such modern fighters as the Fitter (Su-7) and Twin Sukhoi (68-TF), both said to excel the F-4 in air combat.

The Air Force secretary noted that recent Soviet fighter designs concentrated on improving range and payload. US tactical air superiority in the Korean and Vietnam Wars was attributed to 'superior pilot skill and better armament and avionics'. These advantages were not expected to prevail in a conventional war in Europe, for example, because of the likelihood of encountering well-trained Soviet pilots. Moreover, the Soviets were increasing their manoeuvrability edge and significantly improving their missile and fire-control systems. The Air Force cautioned that it could "no longer rely on pilot skill alone to offset any technical inferiority of US aircraft.... To win an air war against Soviet forces it is essential that US pilots be given the best aircraft that technology can afford."

The various Air Force analyses, Secretary Brown said, indicated that little improvement could be expected from modifying existing aircraft such as the F-4, F-111, YF-12, A-7, and a US-German V/STOL design. Additionally, the cost of such an effort would be extremely high, approaching that required to develop a completely new fighter. It conceded that additional study was required to refine the F-X characteristics, but tentatively recommended a 'representative' fighter as: "a 40,000-pound single-place fighter with a variable sweep wing, powered by two high-thrust turbofan engines... capable of sustained flight at Mach 2.3 with a burst capability to Mach 2.5. The avionics... [included] advanced dual mode radar, internally carried penetration aids, and advanced navigation, communications, computation, and identification equipment. The F-X armament will consist of long range radar missiles, short range IR or electrooptical missiles, and an internal gun. [In addition, it] would be equipped to deliver with improved accuracy, all the ballistic air-to-ground munitions and air-to-ground guided missiles in the USAF tactical inventory during the period 1970 to 1980."



Total F-X costs were estimated at $7.183bn, including $615m for R&D, $4.1bn for procurement, and $2.468bn for operations and maintenance over a five-year span. Based on a 1,000 aircraft buy, the average F-X flyaway cost was computed at $2.84m per copy. The proposed initial operational capability (IOC) date was December 1973.

In his memorandum to Mr McNamara, Secretary Brown reiterated that there were several unresolved areas involving the 'Representative F-X', such as whether or not the proposed aircraft could be flown by a single pilot. He said that additional wind-tunnel testing was required to confirm the effectiveness of certain high-lift devices and more detailed work was needed to define the F-X engines and avionics. Dr Brown also foreshadowed the commonality issue by predicting that certain components and subsystems of the F-X and the Navy's VFAX could be made interchangeable. He was less optimistic regarding 'the extent to which common airframe assemblies may be used for these two aircraft'.

The Commonality Issue

By the spring of 1965 there was a general consensus in the Air Force and Navy that the TFX (F-111) would not meet the needs of both services. It was, thus, hardly surprising that in October 1965 the Air Force and Navy independently issued operational requirements for multi-mission fighter aircraft.

Anticipating that OSD might impose a new commonality requirement on them, the services 'agreed to disagree' from the onset. In December they established a joint 'working group of senior officers' to weigh the merits of the commonality philosophy in the development of the next fighter. The effort did little more than stiffen service resistance to the commonality push. General McConnell put the issue succinctly when he stated: "I don't mind the fact that OSD is the decision-maker, but I do mind them telling the services how to prepare their proposals." To head off OSD, the chief established an Air Force F-X study and analysis group under General Kent, AFSC deputy chief of staff for development plans. OSD, however, refused to tolerate this kind of intransigence and in May 1966, McNamara ordered a joint review of the commonality issue. Conducted over the next 18 months, the review confirmed that the needs of the Air Force and Navy could not be met by a single airframe. The two services argued that attempts to merge their requirements would produce, at exorbitant cost, a grotesque mutation with increased weight, and reduced performance. Whereas the Air Force emphasised manoeuvrability performance through low wing loading, the Navy was more concerned with mission versatility, such as extended loiter time for fleet air defence. The services conceded it might be feasible to produce separate airframes - optimised for each service and using essentially common propulsion and avionics subsystems - or to produce variations of a common airframe using common systems, but the potential savings of either alternative could not be estimated accurately without further data. Another element of their proposal was for each service to ask their contractors to submit a service design and a variant for the other service.

The differences that emerged during the joint study convinced some in the Air Force that, like it or not, they were in direct competition with the Navy for money to support development of a new fighter. General Ferguson, among others, sensed the challenge and urged ASD to step up its F-X work. Although the joint position statement satisfied some people in the Air Force, it did not persuade General Disosway, who adamantly opposed a joint program with the Navy. In March 1968, he and General Ferguson warned the chief of staff that the Navy was readying a double-cross, that while the Air Force was engaged in 'playing at the commonality game', the Navy was pressing for approval of one or more new Navy fighters. "We think the time has come," they declared, "for the Air

> **"On December 8, 1965, the Air Force sent requests for proposals (RFPs) to 13 aircraft manufacturers for the initial F-X parametric design studies. "**

BELOW: *The P-47 Thunderbolt is a single-seat, low-wing fighter developed for the US Army Air Force by Republic Aviation and is the largest single-engine piston fighter ever produced.* US Air Force

ABOVE: ***Two ground crew complete the nose art on a P-47 Thunderbolt nicknamed 'Dallas Blonde' at RAF Bodney, Norfolk in 1943.*** *US Air Force*

Force to state its position firmly with regard to the joint aircraft."

An Air Force Position Emerges

Sensing that the Navy was about to promote its new aircraft as an air superiority fighter and convinced that the Air Force could produce a better design, General Disosway decided the time had come to settle the controversy within the Air Force between the multi-purpose and air superiority advocates. In February 1968, he issued TAC Required Operational Capability (ROC) 9-68, an update of the October 1965 QOR. The document cited two new threats in justifying its call for an air superiority fighter. First, the MiG-21, exploiting its ground control interception advantage, continued to trouble USAF fighter pilots in Vietnam. Secondly, the Soviets had displayed several new fighters at the July 1967 Moscow Air Show, and one of these - the Foxbat - was regarded as superior to existing and projected American counterparts (including the 'Representative F-X' described in the August 1967 CFP) in speed, ceiling, and endurance.

To counter this threat, TAC established several 'minimum acceptable requirements': (1) a STOL capability over a 50-foot obstacle with a 4,000-pound load within 3,000 feet; (2) a 230 nautical mile radius of action on internal fuel and 2,600 nautical-mile ferry range with external fuel; (3) speeds between Mach 1.1 on the deck and Mach 2.7 bursts at altitude; (4) high energy manoeuvrability; and (5) one-pilot crew. TAC expressed no preference between fixed and swing-wing designs, or between turbofan and turbojet engines, provided the engine was smokeless. However, even as it attacked the multi-purpose advocates for having undermined the air superiority effort, TAC wanted the F-X to possess an all-weather capability and be able to 'look-down and shoot-down'. Moreover, the ROC specified that the F-X be adaptable for ground support missions once air superiority was achieved.

As noted earlier, the issue concerned means, not ends. Both Headquarters USAF and TAC wanted a new fighter, but the multi-purpose advocates believed it best to present the F-X as a successor to the F-4, whereas the air superiority proponents were equally convinced that only their approach could defeat the Navy's bid. At any rate, by early 1968, the air superiority advocates had gained the upper hand. A decisive factor favouring the air superiority school was that two fighter 'types' - Generals Disosway and Holloway - occupied key positions at the same time and fought persistently for their viewpoint. However, the fear that the Navy would walk off with the prize unless the Air Force decided to 'speak with one voice' united the factions. In May 1968, General McConnell explained the Air Force position to the Senate's Armed Services Committee: "We had a very difficult time in satisfying all the people who had to be satisfied as to what the F-X was going to be. In fact, we had a difficult time within the Air Force. There were a lot of people in the Air Force who wanted to make the F-X into another F-4 type of aircraft. We finally decided - and I hope there is no one who still disagrees - that this aircraft is going to be an air superiority fighter."

"The various Air Force analyses, Secretary Brown said, indicated that little improvement could be expected from modifying existing aircraft such as the F-4, F-111, YF-12, A-7, and a US-German V/STOL design. "

When asked if the F-X might also be used for close air support, the Air Force chief of staff replied, "It would be over my dead body."

Meanwhile, the Navy had undertaken to improve its fighter's energy manoeuvrability characteristics whenever the Air Force did so. Dissatisfied with the VFAX, its replacement for the F-111B model of the TFX, the Navy decided to cancel it and tacitly accept an unsolicited bid from Grumman Aircraft - a traditional Navy contractor - to develop a more competitive fighter. Designated the VFX, the Navy's proposed aircraft combined previous multi-mission requirements including air superiority, in two variant designs - the VFX-1 and the VFX-2. The Navy now argued that the VFX not only could match the F-X performance but was also adaptable to both carrier and land-based operations.

Clearly, the Air Force's task was to counter Navy strategy by presenting an unqualified air superiority fighter - one uncompromised by secondary mission requirements. One compromise remained, however - namely, the F-X had to accommodate Sparrow missiles to shoot down the high-flying, high-speed Soviet Foxbat.

In May 1968, General McConnell assigned top priority to the F-X program and designated January 1, 1969, as the target date for implementing contract definition. This meant strengthening the F-X programme office at Wright-Patterson Air Force Base, Ohio, and providing all available manpower or other resources to get the job done. Further encouragement came from Dr John Foster (the new DDR&E) who predicted that the F-X would get OSD approval by September 1968. AFSC's vice-commander, Lieutenant

BELOW:
F-4D Phantom 65-0647 assigned to the North Dakota Air National Guard's 119th Fighter Wing 'Happy Hooligans', armed with AIM-7 Sparrow missiles over the Arctic Ocean, during a mission from Naval Air Station Keflavik, Iceland in 1983. *US Air Force*

General Charles Terhune, stressed the importance of running an exemplary programme to gain support for the F-X from the next administration which would take office in January 1969.

By the spring of 1968, DDR&E accepted that its commonality drive had petered out. Dr Foster recommended, however, that the Air Force and Navy conduct a joint engine development program - the one item both services had agreed upon. (The Navy was interested in the engine because it would provide more thrust than the TF30 engine intended for the VFX). In June, Assistant Secretary of the Air Force for R&D, Alexander Flax, told AFSC to proceed with a unilateral programme because he considered the commonality issue dead. To unify the effort, the Air Force made Brigadier General Roger Rhodarmer liaison for F-X activities. He proceeded to select a staff of fighter pilots including Colonels John Boyd and Robert Titus and Major John Axley, to help him sell the F-X program. General Rhodarmer saw his task as twofold: First, he had to achieve a unified position within the Air Force, specifically by resolving outstanding differences. This was no mean task, since TAC and ASD continued to clash over the basics as the F-X's maximum speed, energy manoeuvrability and structural loads. The second task was to steer the F-X documentation through OSD and Congress.

Point Design Studies

Meanwhile, on August 11, 1967 the Air Force had solicited bids from seven aerospace companies for a second round of studies. These 'point design' studies sought to refine the F-X concept in four areas: (1) validating the aircraft's performance in wind tunnel tests; (2) matching propulsion requirements against performance; (3) examining the preferred avionics and armaments systems; and (4) studying the effects of crew size. In short, the effort was to establish a technical base for the F-X proposal. On December 1, the Air Force awarded study contracts to General Dynamics and McDonnell-Douglas, while Fairchild-Hiller, Grumman, Lockheed, and North American undertook unfunded studies. All investigations were completed by June 1968, at which time a composite Air Force team assembled at Wright-Patterson Air Force Base, Ohio, to 'scrub down' the results and rewrite the Concept Formulation Package.

More than 100 people helped in the scrub down effort headed by Colonel Robert Daly. The basic airframe issues were resolved within reasonable time, but the avionics caused considerable disagreement. A major issue in the avionics controversy concerned the F-X fire control system. Specifically, the multi-purpose advocates tried to retain such items as terrain-following radar and blind-bombing capability. They argued that 'advances' in radar, antennas, and computers would permit inclusion of these features, but overlooked both the costs and risks involved. The scrub down was only partly successful since many high-risk, high-cost items remained.

CFP Supplement

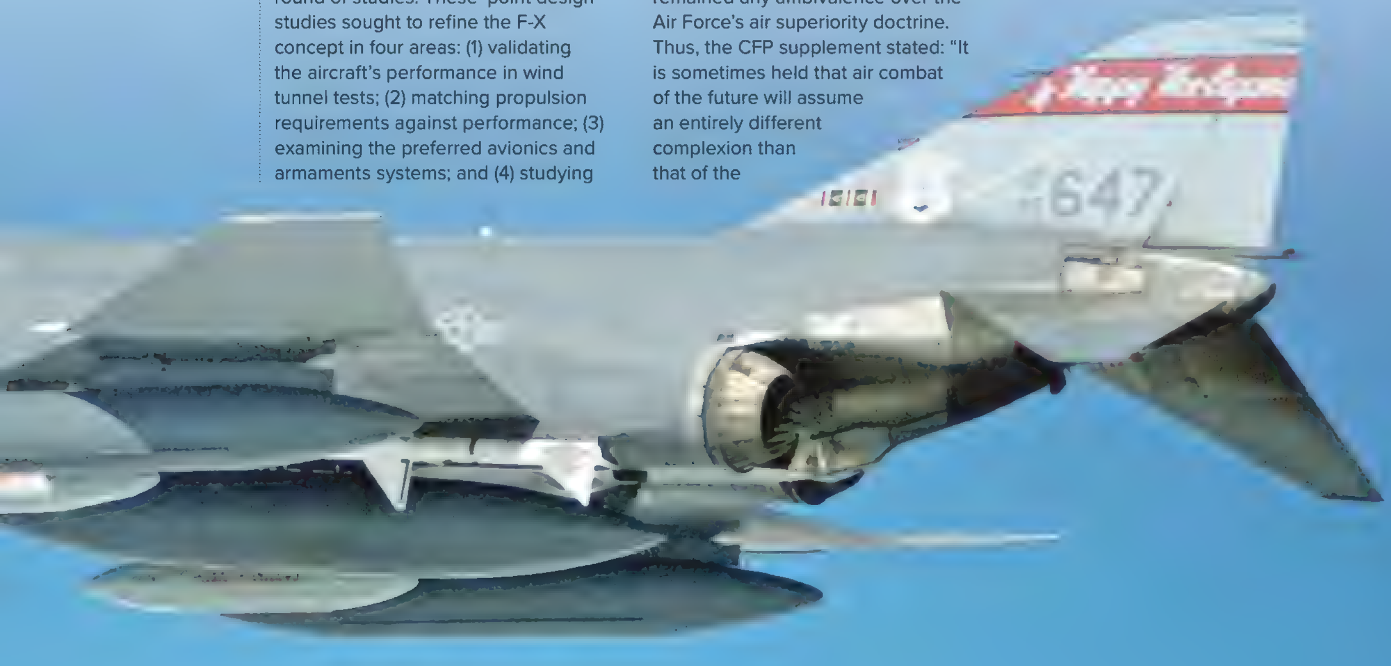
Although differences remained, the point design-studies and scrub down proved fruitful. In August 1968, the Air Staff issued a supplement to the CFP that not only updated the original formulation document but also recommended some fundamental changes. For example, there no longer remained any ambivalence over the Air Force's air superiority doctrine. Thus, the CFP supplement stated: "It is sometimes held that air combat of the future will assume an entirely different complexion than that of the past. The Air Force does not share that contention. To the contrary, tactical applications of air superiority forces will remain essentially the same for the foreseeable future."

It further noted that the war in Southeast Asia had taught the Air Force that smaller-sized aircraft could better escape radar and visual detection. Thus, the supplement specified a one-man crew for the F-X but retained a two-man trainer version. The wing planform remained open, although the 'Representative F-X' described a swing-wing rather than a fixed-wing design. The major subsystems - engine, radar, and cannon - would be selected on a competitive flyoff basis. While the Air Force did not resolve some of the difficult issues, it decided to stress the air superiority aspects of the F-X and relegated to a secondary or bonus status air-to-ground capabilities.

F-X costs in the August 1968 CFP supplement were presented on a different basis than they had been the previous year. In 1967, for example, cost estimates had been predicted on a 10-year, 1,000 aircraft buy, whereas the 1968 estimates considered a 635-aircraft production run.

1968 F-X Cost Estimates in millions

Development costs	$1,162.46
Investment costs	$7,070.29
Flyaway cost/aircraft	$4.68
Operating costs	$5,666.71
Total system cost	$13,899.46



On August 15, General McConnell approved the F-X source selection plans and the joint Air Force-Navy engine development programme. Secretary Brown's endorsement came the next month.

The final task in the concept formulation phase was to write an F-X Development Concept Paper (DCP). Prepared by DDR&E's staff with Air Force assistance, the DCP described the F-X as 'a single-place, twin-engine aircraft featuring excellent pilot visibility, with internal fuel sized for 260 nautical mile design mission, and... a balanced combination of standoff [missiles] and close-in [cannon] target kill potential'. The one-man crew decision, validated during the point design studies, was predicated on the ability of a single pilot to perform nearly all missions assigned. The penalties for adding a second crewman, which included 5,000 to 6,000 pounds of extra weight at a cost of $500,000 per aircraft, were considered unacceptable. The twin-engine design was selected because it featured faster throttling response, commonality with the F-14, and earlier availability.

The DCP called for a 260 nautical mile mission radius including a 200 nautical mile cruise out and back, and a 60 nautical mile low altitude terminal dash with between 2.5 and 3 minutes of maximum power combat time. This capability replaced TAC's original requirement for a 100 nautical mile dash with five minutes combat time. Still, the internal fuel load, plus the external tanks going out, provided the F-X with an 800 to 850 nautical mile radius of action compared to the 450 nautical miles for the F-4. Operational experience in World War Two, Korea, and Vietnam influenced this decision by showing that the amount of internal fuel determined fighter performance and combat time over enemy territory.

In terms of speed, there was some compromise away from TAC's original requirements. The sea level maximum speed was set at Mach 1.2, to provide a continued US advantage over Soviet fighters in that region, although relaxing the requirement to Mach 0.9 could have saved 2,000 pounds in weight. Similarly, TAC settled for a maximum speed of Mach 2.3, with bursts of Mach 2.5, as against its original Mach 2.7 requirement that would have added 3,000 pounds to the F-X weight and reduced its dash radius to 30 nautical miles. The Development Concept Paper failed to point out that to try to achieve Mach 2.7 would have greatly increased the cost of the F-X because of the added titanium metal content.

The most ambiguous features, however, involved the F-X radar and avionics packages, which were lumped together as 'flexible vs. specialized counterair capability'. Accordingly, such items as the 'auxiliary power unit, soft-field landing gear, tail hook, drag chute, auto-pilot, self-sealing or foamed fuel tanks, armour, and bullet-proof glass' were justified on the basis of their survivability features. This equipment increased the aircraft's load factor (from 6.5g at 60% fuel to 7.33g at 80% fuel) and gross weight (from 30,000-35,000 pounds to 40,000 pounds) but was justified as necessary for the early detection of the enemy. Feather Duster and Have Doughnut, two tactical-fighter flight tests conducted in 1968, showed that early detection of enemy aircraft

"The F-15's armament included both missiles and an internal cannon. The air force added the gun on the advice of veteran pilots and Vietnam returnees as well in light of the Israeli success [a 54-0 air-to-air victory over Arab fighters] with cannon in the Six-Day War during June 1967."

US Air Force/Larry Harrington

was essential to permit a pilot to get into position for a first - and usually lethal - shot. Thus, the choice was between a smaller, lighter aircraft that would be difficult for the enemy to detect and a larger aircraft like the F-X that could more easily detect an enemy aircraft. Although selecting the latter, the Air Force left open a final trade-off until sometime during the contract definition phase.

Cost-estimates changed again because of a revised aircraft buy. The Air Force's future tactical force had been restructured to 29 wings, including nine F-4, five F-X, seven F-111, four A-7 and four A-X (later A-10) wings. This plan required only 520 aircraft.

Prototyping Rejected

The final issue in the F-X DCP was whether to pursue contract definition or prototyping for aircraft procurement. Dr Foster, who had succeeded Brown as DDR&E, supported the Air Force's request to begin contract definition immediately, whereas Dr Enthoven favoured a nine-month postponement to permit study of a smaller, lighter-weight fighter that would be 'based on the competitive prototype approach'. The Air Force argued it could afford neither the delay nor the estimated $600,000 cost of prototyping. Moreover, the Air Force indicated that the aerodynamic and avionics risks were not great enough to require building a prototype.

Actually, the Air Force position on this issue had grown out of a 'sense of urgency' because of the challenge from the Navy's VFX and the inauguration of a new president who would make the usual changes in OSD's civilian leadership. The Air Force, therefore, found it expedient to 'keynote... urgency over ideal procurement'. The F-X airframe would be purchased via the Total Package Procurement concept, but higher risk subsystems would undergo competitive prototyping. Both those who favoured 'total package' and the prototype advocates believed that their particular approach would prove faster in the long run.

Two other alternatives - to improve the F-4 and to develop the Navy's VFX (F-14) for the Air Force - were dismissed because of cost and mission incompatibility. On September 28, 1968, Deputy Secretary of Defense Paul Nitze approved contract definition of the F-X.

These efforts demonstrated that, although differences remained within the Air Force, outwardly it could present a unified stand. The Air Force had won approval to develop a new fighter (the F-X becoming the F-15), marshalled its resources toward that goal, and established a central office in Washington to deal with whatever problems arose.

Contract Definition

On September 30, 1968, the Air Force launched the F-X contract definition phase by soliciting bids from eight aircraft companies. Only four contractors responded - Fairchild-Hiller, General Dynamics, McDonnell Douglas, and North American. Four other firms - Boeing, Lockheed, Grumman, and Northrop - had participated in the concept formulation effort but did not submit proposals. In November and December, the Aeronautical Systems Division, and the F-15 programme office (established in August 1966) began evaluating the four proposals and negotiating with the firms. On December 30,1968, Dr Flax announced the award of $15.4m in contracts for contract definition to all bidders except General Dynamics. They were asked to submit technical proposals - including the projected cost of the aircraft and a development schedule - by the end of June 1969.

As contract definition began, a question arose over the number of competitors the Air Force should maintain and for what length of time. In February 1969, shortly after becoming Secretary of the Air Force, Dr Robert Seamans issued new guidelines to reduce the number of contractors. These guidelines required the firms to indicate the number of workers and the amounts of other resources that each proposed to devote to the competition and updated information on their planning and organisation, their record of correcting deficiencies, and the effect their other aircraft programs might exert on the F-15. Dr Seamans also assigned Robert Charles, his assistant for installations and logistics (I&L) to investigate each firm's ability to assume the commitments and risks required by the new contractual approach. Secretary Seamans hoped the information obtained would enable him to eliminate one of the three contractors by April and another by September 1969.

Dr Foster, on the other hand, believed that the three F-15 contestants should continue to compete for a longer period, and he suggested the Air Force extend the competition to January 1970. He thought the delay would be well worth the extra costs and that the extended competition might prove a good investment in terms of the final cost of the F-15 development contract.

New Contracting Philosophy

Meanwhile, a rising tide of public and congressional criticism over the enormous cost overruns in the C-5A program forced the Air Force to drop its plan to procure the F-15 under the fixed-price 'total package' concept used for the huge cargo aircraft. Major General Harry Goldsworthy, ASD commander, was directed to set up a study group to recommend an alternative approach. In a report to General Ferguson, Goldsworthy pointed out that while no single element of the F-15 proposal represented an inordinate technical risk, its proposed integrated system would be a major challenge to an industry that had little recent experience in developing an air superiority fighter. Moreover, he maintained that cost estimates for an aircraft yet to be designed were highly unreliable, especially considering the five to seven-year lead time required to build a new fighter.

The ASD commander cited the C-5A experience as demonstrating the futility of relying on cost projections for long-term programs. Although 'total package' could stabilise engineering changes and quantity schedules, it also inhibited technical innovation because it tied the contractor to a fixed-price arrangement that emphasised cost over performance. Thus, Goldsworthy advocated some kind of production commitment during the competitive phase of the

programme but only if it also protected the contractor against unreasonable financial risk. As a corrective, he recommended relying on a cost-type arrangement for the development phase with a fixed-price incentive provision to govern the production phase.

Another weakness seen in the 'total package' procurement approach was that it committed the government to production without providing adequate control over technical development and allowed the contractor to adjust designs and costs during development. General Goldsworthy believed that if the contractor's financial risk were minimised, he would not 'cut corners' and therefore would produce a better aircraft. Moreover, by allowing the Air Force to authorise initial production and permit separate prototype development for the high-risk subsystems, the new approach would avoid later modifications because of inadequate design. Finally, this approach reduced concurrency between production and development by proof-testing the weapon system prior to releasing it to largescale production.

ABOVE: ***Maintenance crews prepare 119th Fighter Wing F-4D Phantom 64-0963 at Ramstein Air Base, West Germany in June 1987 during Operation Creek Klaxon, an exercise involving Air National Guard units from 20 states deployed to temporarily assume the Zulu Alert duties of the then resident 526th Tactical Fighter Squadron.*** *US Air Force/CMSgt Don Sutherland*

Selling the New Approach

If the Air Force seemed satisfied with the Goldsworthy procurement method, OSD was not. Through the spring and early summer of 1969, Secretary Seamans pressed OSD to grant its approval. Dr Foster, however, continued to act as a 'nemesis' by opposing anything other than a fixed-price contractual arrangement. Preoccupied with spiralling costs for tactical weapons, he cautioned that the F-15 might have to be placed 'on an equal-cost basis', in which 'explicit force trade-offs' would have to be specified and 'either the number of aircraft or other Air Force tactical air programs would have to be reduced'. To avert this compromise, Dr Foster urged the Air Force to monitor the F-15's cost-growth closely and advise its contractors that it sought an aircraft that would achieve the majority of its design objectives.

Meanwhile, although he was said to favour the Air Force plan, Deputy Secretary of Defense David Packard had not decided. At a crucial meeting with Seamans in June, he conceded it was unrealistic to delay further the setting of a price for the F-15. Packard indicated his preference for the 'soundest-priced' aircraft over the cheapest one and agreed that the development and production phases ought to be conducted separately. However, the unresolved question remained whether to proceed with a cost-type development contract.

With OSD delaying its authorisation, Secretary Seamans was forced to withdraw his original February 1969 guidance to the contractors regarding the proposed production schedules and to ask them to provide ceiling-price estimates that the Air Force might invoke at its discretion. He also requested the firm to submit a plan to maintain a production capability until production approval was granted. Finally, he asked the contractors to propose a set of demonstration milestones that they would be committed to reach so as to 'provide technical confidence in the programme'. These milestones, which were to prove central to the new weapon system acquisition approach, would be negotiated with the successful bidder.

Dr Foster, continuing to insist that a fixed-price arrangement was the only approach he would support, recommended another round of design studies to reduce the F-15's requirements and realign the aircraft's flyaway costs to the $5.33m figure specified in the DCP. Though opposed to his reasoning, the Air Force offered to ease some of the aircraft's air-to-ground mission requirements. On June 27, with contract time running out, Secretary Seamans appealed once again to the Deputy Secretary of Defense. That same day, Secretary Packard gave the Air Force the go-ahead on its F-15 contracting method.

The F-15 contract negotiations, conducted during November and December 1969, involved a total of six contracts with three airframe companies. Each company also signed contracts with two engine manufacturers. The idea was to have all these contracts in force, pending first the Air Force's selection of an airframe builder and, following that, the engine developer. In effect, the Air Force obtained commitments without having to wait for the results of the competitions.

Although Dr Foster continued to provide 'informal direction' to the F-15 Program Office, the new contracting method remained intact. Air Force officials did not delude themselves into thinking that the milestone contracting method offered any more than a first step in the right direction. Conducting a detailed and frank self-analysis of the problems that they might face with the contract, they apparently resolved most of them before selecting the winning contractor.

The F-15 Program Office

Several years before contract negotiations began, the Air Force established an F-X special projects office at WrightPatterson Air Force Base, Ohio, to oversee development of both the F-X and A-X close air support aircraft. The office first came under ASD's Deputy for Advanced Systems Planning, more specifically, the General Purpose Planning Division. Established on August 12, 1966, it was initially headed by Colonel Robert Daly and allotted 17 'validated' positions.

Throughout 1967, Colonel Daly's staff was preoccupied with the task of preparing the F-X concept formulation documents. These ranged from a description of the programme to documents dealing with planning, programming, and funding. The System Program Office (SPO) also provided extensive data to satisfy OSD's demands for a proposed joint Air Force and Navy advanced tactical fighter. Headquarters USAF established January 1969 as the target date to begin contract definition, and in May 1968 the A-X (later A-10) close support fighter SPO was separated from the F-X and set-up as a separate entity. In June 1968, Colonel Robert White became the new SPO director.

With the creation of the F-X focal point in Washington in the spring of 1968,

BELOW: ***The F-15 made its ceremonial debut at McDonnell-Douglas' St Louis plant on June 26, 1972. Appropriately painted in air superiority blue and christened the Eagle, it was hailed as America's first air superiority fighter since the F-86 appeared some 20 years earlier.*** *Boeing/ McDonnell-Douglas*

the SPO was spared the press attention normally devoted to a weapon system development program. Following OSD's approval of the F-X DCP in September 1968, the SPO was reorganised on October 7 and assigned to the Deputy for Systems Management for both operational and administrative support. A number of internal changes occurred at this time, including setting up four divisions: configuration management program control, procurement and production, and test and deployment. Generally, however, the SPO continued to perform the mundane functions of management.

An important change that affected the F-15 SPO took place on July 11, 1969 when Brigadier General designee Benjamin Bellis was named its new director, replacing Colonel White who became his deputy. General Bellis was one of the Air Force's most experienced R& D managers, with service dating back to a 1947 assignment to the Special Weapons Project at Sandia Base, New Mexico. Having made his reputation in the development field with the Matador and Atlas missiles, he later managed the F-12/SR-71 aircraft development project and served as ASD deputy for reconnaissance and electronic warfare before assuming the F-15 directorship. In addition, General Bellis had written the Air Force 375-series management regulations, acquired his own warrant as a procurement specialist and earned advanced degrees in aeronautical engineering and business administration. Considered the ideal man to direct the Air Force's top priority F-15 programme, he was the unanimous choice of Secretary Seamans and Generals Ferguson and John Ryan the new Air Force Chief of Staff.

By July 1969, the F-15 had become identified as the model development and procurement programme for both the Air Force and OSD. Recognising the program's important status, the Air Force broadened the authority of the new director. In reviewing his responsibilities, General Bellis, too, was well aware of their importance. Describing his role in 1970, he said: "I am the single individual who must account for the progress, expenditure of funds, problems and solutions that will make the F-15 a successful part of the Air Force inventory. . . . I can hold down changes that might only add higher costs and complexity without increasing the true capability of the F-15 fighter. I am the single source of decision for integrating all elements of the system, and this allows me a proper perspective on total dollar costs and technical progress. With this type of control, there can be no excuses for uncontrolled changes."

General Bellis later expressed his confidence in the programme, saying: "we will not only produce the number-one aircraft in the US inventory but also re-establish the Air Force's credibility as a manager of major weapon system programs and regain the confidence and support of the Congress and the taxpayer."

On October19, the F-15 office became a 'Super SPO' when General Bellis was named deputy for F-15. In reporting directly to the AFSC commander, he bypassed ASD, which remained responsible for providing administrative support only. To centralise control, the new F-15 Deputy reorganised the SPO, assuming total responsibility for programme management, including the engine, armaments, and avionics systems. The Joint Engine Program Office (JEPO) became a component of the F-15 SPO. Colonel Wenzel, who headed the engine office and had a naval officer as deputy, answered to General Bellis, but the deputy reported to the Navy's F-14 programme manager.

General Bellis, in turn, reported on the engine programme to both AFSC and the chief of the Naval Materiel Command. The JEPO was self-sufficient in procurement, engineering, and testing, but relied on the F-15 SPO for functional assistance.

General Bellis was also given authority to select the best personnel he could find to join the F-15 project. Following cancellation of the Manned Orbital

Laboratory programme in June 1969, he was able to handpick top-calibre staff, which in a short time grew to about 230 people - half military and half civilian. The prestigious F-15 assignment attracted many experienced, highly competent people to the programme. Moreover, because General Bellis was keenly interested in the career advancement of his staff, he was able to build a tightly-knit and well-motivated group.

After studying the SPO's internal organisation, General Bellis increased the number of its directorates to include procurement and production, test and deployment, configuration management, integrated logistics support, program control, systems engineering, and projects. The last-named was unique in that it was responsible for ensuring that its vital components - airframe, avionics, and armaments - were developed and available when needed. This arrangement permitted General Bellis to exercise strict control over systems development.

General Bellis' staff also included liaison officers from TAC, Air Training Command (ATC), and Air Force Logistics Command (AFLC). Their function was to provide close coordination with the user commands so that the first F-15 wing could become fully operational at the end of the development and testing phases. For example, a Systems Application Panel brought together veteran TAC pilots to make sure the F-15 would remain a 'fighter pilot's plane'. Finally, General Bellis established a Straight Arrow Group to guard against improper conduct between SPO personnel and the F-15 contractors.

However, some aspects of General Bellis' management caused controversy. For example, he was sometimes overly secretive in managing the F-15 office - a tendency that probably derived from his experience with the 'hush-hush' SR-71 project. General Bellis believed that he alone was responsible for programme management and brooked no outside interference. His tough stance that the Air Force could replace him whenever it felt he was not doing his job embittered his relations at times with officials in the Air Force Secretariat who were authorised to monitor the F-15 program. By concentrating authority within the SPO, General Bellis made outside inspection of his activities difficult. Indeed, during the source selection phase in the late summer and fall of 1969, he complained about the intensive scrutiny that the F-15 was receiving from various agencies. As a result, Secretaries Seamans and Packard instructed Air Force and OSD officials to operate strictly through the F-15 SPO in their work.

ABOVE: ***The first F-15A Eagle 71-0280 parked outside the McDonnell-Douglas production facility at St Louis in 1972.*** *Boeing/McDonnell-Douglas*

Management Facelift

The F-15 reorganisation marked the beginning of a thorough housecleaning of the Air Force's management procedures. Under congressional pressure because of the unhappy C-5A experience, Defense Secretary Melvin Laird decided that a presidential 'blue ribbon' panel should examine the department's procedures. However, because the development problems could not wait, Secretary Packard conducted his own assessment. Concluding that 'total package' was not working, he undertook to make extensive changes. His first action was to eliminate unessential layers of staff in decision-making. He also improved cost-estimating procedures and placed greater emphasis on prototyping i.e., 'flying before buying'.

In April 1969, anticipating the need to improve the Air Force weapon-system acquisition process, General Ferguson decided to centralise programme control. He advised ASD that all configuration changes for the F-15 "affecting the mission, increasing the weight or target cost, and impacting the schedule" would be approved by a triumvirate including himself, General Ryan, and Lieutenant General Marvin McNickle, the deputy chief of staff (R&D). Next, General Ferguson convinced Secretary Seamans and General Ryan to reorient the Air Force management philosophy. The first step was to get the Air Staff out of the management 'business' by shifting the Program Element Monitor (PEM) function to AFSC. This move, effective August 1, 1969, freed the Air Staff to 'focus on policy and plans', and enabled General Ferguson as AFSC commander to monitor the programme through the new F-15 SPO. However, his recommendation to establish an AFSC liaison office in the Pentagon was turned down.

The new reporting channel - from Bellis to Ferguson to Ryan and Seamans - was called the Blue Line. It fulfilled the Air Force's decision to 'reduce the number of review echelons'. The AFSC programme monitor, known as the assistant for F-15, assumed the duties previously assigned to General Rhodarmer during the F-15 advocacy stage and also served as the Washington area focal point for all F-15 matters. The monitor briefed the Air Staff monthly on the F-15's progress, while General Bellis presented quarterly briefings and written reports - known as Selected Assessment Reviews - to Secretary Seamans, General Ryan, and both top officials. This arrangement ensured tight programme control and released the F-15 SPO to concentrate on day-to-day management activities.

These streamlined procedures, which closely paralleled Secretary Packard's views on weapon system management, account for the harmonious relationship that existed between OSD and the Air Force on the F-15 program. After meeting with General Ferguson in June 1969, Secretary Packard established specific guidelines for weapon-system managers: (1) use a standard programme information format for OSD, USAF, and AFSC; (2) reduce paperwork by providing less detailed information at each successively higher level; (3) ensure decisions are made expeditiously, with authority delegated to the SPO; (4) definitize all changes in weapons; and (5) weigh costs against schedule and performance factors in approving changes in weapons under development with contractors. In May 1970, after having formalised these weapon-system management principles, Secretary Packard sent memorandums to the service

secretaries in which he emphasised that OSD's role was to "enable the services to improve their management of WS [weapon system] programmes. Improvement in the execution of these programmes will be made to the extent the Services are willing and able to improve their management practices. The Services have the responsibility to get the job done. It's imperative they do the job better in the future than in the past."

Source Selection

On July 1, 1969, the three F-15 airframe competitors - Fairchild-Hiller, McDonnell-Douglas, and North American - submitted technical proposals and two months later, on August 30, their cost proposals. The Source Selection Evaluation Board (SSEB) headed by General Bellis, then evaluated these bids, examining 87 separate factors under four major categories - technology, logistics, operations, and management. They rated the competitors in each category and, without making a recommendation, submitted the raw data to a Source Selection Advisory Council (SSAC), comprised of representatives from the user commands and chaired by Major General Lee Gossick, the ASD commander. The council then applied a set of previously established weighting factors that they had defined in June 1969, before the start of the evaluation. Although rating the contractors in the four major categories, the council, too did not select a winner. Instead, it forwarded the scores through the Air Staff to Secretary Seamans, who as Source Selection Authority (SSA), was the final decision-maker.

Project Focus

During this evaluation, however, Secretary Packard directed the Air Force to minimise costs by making a thorough final review (Project Focus) of the F-15 program requirements. He acknowledged that the review, in taking several months to complete, would delay the F-15 IOC date, but he felt this compromise would be worthwhile if it avoided costly mistakes. The deputy secretary also clamped a $1bn per year spending limit on the F-15 programme and directed that Project Focus be completed by mid-November 1969 to avoid disturbing the source-selection process. Sensitive to criticism of the F-15 programme, he especially examined recommendations for alternate avionics, simpler data and reporting systems, reducing airframe costs, alternate subsystems, and contractor suggestions.

In October 1969, Dr Foster (DDR&E) resumed his campaign to extend the F-15 selection process by more thoroughly evaluating the contractor proposals. Citing the F-111 and C-5A competitions as examples of programmes that had suffered from inadequate evaluation, he stated that last-minute changes were the cause of their problems. Dr Foster also warned that F-15 cost estimates had already exceeded the September 1968 DCP threshold and asked the Air Force to control escalating costs. Ivan Selin, OSD's chief for systems analysis, echoed Foster's concern over the rising costs and hinted that further cuts might be in order.

Meanwhile, the Air Force had acted promptly to meet Secretary Packard's call for a program review. General Bellis established a Program Evaluation Group (PEG) to define a $1bn annual production plan, restrict development funds in FY1970 through 1972, and cut unit production costs. The group quickly suggested a long list of items to reduce F-15 costs by more than $1.5m per aircraft. As a result of Project Focus the following actions were taken to hold down F-15 costs.

Aircraft

Windshield bird-proof requirement deleted
- Use 'Fail Safe' in lieu of 'Fail Operational' flight control system
- Use F-105 escape seat technology
- Install M61 gun (provide for 25mm gun)
- Delete nuclear curtain
- Delete pressure suit
- Delete voice warning
- Eliminate soft field landing requirement
- Evaluate material usage
- Reduce training requirements
- Reduce MIS satellite complex
- Reduce data requirements

Avionics

- Replace vertical tapes with round dials

In the radar

- Delete parametric amplifiers
- Delete low PRF long range mode
- Reduce threshold of sizable clutter
- Simplified digital signal processor
- Reduced air-to-ground map range
- Delete inflight fault isolation
- Eliminate hydraulic boresight
- Reduce computation requirement, eliminate one computer using off-the-shelf communications equipment

BELOW: *F-15A 71-0280 during its first flight on July 27, 1972 piloted by McDonnell-Douglas' chief test pilot Irving Burrows. The 50-minute maiden flight was flown from Edwards Air Force Base, California.* US Air Force

- Reduce inertial navigation accuracy requirements using off-the-shelf navigational instrument
- Reduced IFF and TEWS packages

Test

- Combined testing where common instrumentation existed
- Reduce flight test hours
- Reduce spares and spare parts
- Modified system demonstrations
- Delete High performance test bed
- Reduce air-to-ground delivery qualifications

The Air Force asked its contractors to update their costs proposals in October 1969. McDonnell Douglas, reducing its cost estimate by about $500,000, submitted the lowest revised bid. The cost review continued throughout the F-15 project and a subsequent General Accounting Office (GAO) report in July 1970 credited it with about $1bn in savings. In December 1969, encouraged by the work of Project Focus, Secretary Packard authorised the Air Force to go forward with the F-15 development.

McDonnell Wins

Secretary Seamans, having announced the award of the

F-15 contract to McDonnell-Douglas on December 23, 1969, estimated that the development phase, including the design and fabrication of 20 aircraft, would cost $1.1bn. Donald Malvern, McDonnell's F-15 general manager, reported that the firm had already spent five million man-hours in winning the F-15 contract. His team of between 200 and 1,000 people had worked for two years examining over 100 alternative designs with thousands of variations. From an economic standpoint, the F-15 contract 'saved' one third of the company's 33,000 jobs in the St Louis, Missouri, area despite the fact that in 1968 McDonnell led the nation's aerospace firms, earning $95m on revenues of $3.6bn. The F-15 contract also promised to increase McDonnell's sagging commercial airliner sales and absorb the slack of lowered F-4 production.

As for the losers, North American planned to lay off 1,500 of its 6, 500 Los Angeles Division employees. Ironically, the company had reduced its Advanced Manned Strategic Aircraft (AMSA) effort in May 1969 to concentrate on the F-15 competition but went on to win the bomber project in June 1970. The smallest of the three companies, Fairchild-Hiller, failed to establish itself as a major defence contractor, though it did win the A-X (A-10) competition in 1973.

Air Force Weathers Congressional Scrutiny

Before and after the award of the contract to McDonnellDouglas, the F-15 competition was the target of considerable scrutiny from congress and the media. One of the thorniest issues concerned disclosure of the Air Force's source selection criteria. In July 1969, John Blandford, chief counsel for the House Armed Services Committee (HASC), asked the Air Force to reveal this information. Assistant Air Force Secretary Philip Whittaker opposed meeting the request because, he argued, it would set an 'extremely bad precedent'. He won a reprieve until after contract award by explaining to the committee that the release of the criteria would compromise 'business confidentiality'. Even when the competition was completed, Secretary Whittaker parcelled out only selective bits of information to congress.

In a November 22 article in the Armed Forces Journal, writer Bruce Cossaboom charged that the Air Force had illegally withheld disclosure of the F-15 source selection weighting factors from the contractors. Representative Otis Pike (Dem-NY), a frequent critic of defence spending, brought the case to the House floor in December 1969, charging the Air Force with violating Section 2271, Chapter 135, Title 10 of the US Code 49. When Chairman Mendel Rivers (HASC) asked the Air Force to respond, Secretary Seamans labelled Cossaboom's charges 'mistaken' because they were based on an obsolete Air Corps Act of 1926. Reviewing the Act's legislative history, the secretary noted that the Air Force could furnish the weighting factors, but that such an action was 'in no sense mandatory'. He also reminded his critics that the selection criteria had been established on June 2, 1969, before

ABOVE: ***This photo of F-15A 71-0280 during an early test flight from Edwards Air Force Base shows the full extent of the high-visibility dayglo colour applied to different surfaces on the aircraft. During the F-15's flight test programme, this aircraft was used to explore the flight envelope, general handling and carriage of external stores.*** *US Air Force*

the contractors had submitted their proposals. Though further explaining the source selection process, he did not divulge the requested criteria. The Air Force position in this case was later vindicated through a GAO investigation that found itself 'in full agreement with the Air Force' on the interpretation of the 1926 Act.

Throughout the F-15's contract award 'countdown', the Air Force's policy of gingerly sidestepping a torrent of political pressure and influence peddling avoided the usual charges of favouritism that follow a weapon-system contest. In fact, Fairchild-Hiller's president, Edward Uhl, endorsed the Air Force's handling of the F-15 competition as having "been conducted in a most professional manner and fairly run."

A second controversial issue that threatened to delay the F-15's development concerned alleged discriminatory employment practices at McDonnell's St Louis plant. 'A major flap arose today', began Under-Secretary of the Air Force, John McLucas, in a January 21, 1970 memorandum explaining why the Air Force had failed to obtain McDonnell-Douglas' compliance with minority employment laws before contract award. Caused by the inadvertent use of an obsolete checklist that omitted the requirement, this procedural error could have revoked the F-15 contract. Further, since the fault was solely theirs, the Air Force stood to pay any resulting contract termination costs.

The incident came at a time when McDonnell's employment record was under intense public attack. Local militants and the prestigious US Commission on Civil Rights charged that, although African Americans accounted for half the St Louis population, only about 8% of McDonnell's work force was African American. They also cited as inadequate the company's equal-opportunity employment plan filed at the Department of Labor's St Louis office in December 1969. With the expected involvement of Senator Edward Kennedy (Dem-Mass) lending an added political voice, OSD officials scrambled to solve the problem.

Secretary Laird sent his assistant for Manpower and Reserve Affairs, Roger Kelly, to iron out the matter personally with McDonnell, and Dr Seamans interrupted a conference he was attending in Puerto Rico to meet contractor officials in St Louis. The Air Force bluntly told McDonnell to draft an acceptable equal opportunity employment plan or risk losing its F-15 contract as well as 'all other Government programmes'. Responding to his pressure and bad publicity, McDonnell negotiated a new plan. Announced on February 11, 1970, the plan's key features included a provision to raise minority hiring and upgrading levels to 15.8% during 1970, establish a $1m training program, and expand open housing. The Air Force's decisiveness and quick action thus averted a potentially damaging blow to the F-15 program.

The Sub-Systems

Although USAF officials had rejected a prototype competition for the F-15 airframe contract, they readily pursued this approach for the aircraft's subsystems. The explanation was simple since the engine, radar, and short-range missile were the critical subsystems, a prototype competition among several contractors would reduce programme costs and risks. System contractors were to be selected on the basis of proof-testing and demonstration of subsystem prototypes.

The Engine

In December 1967, the Air Force and Navy agreed to conduct a joint engine-development program. Their goal was to develop a high-performance afterburning turbofan Advanced Technology Engine (ATE), drawing on the experience gained in the development of the lift-cruise engine of the US-West German V/STOL and AMSA bomber programmes. The proposed new engine was required to produce 40% more thrust and weigh 25% less than the 12-year-old TF30 engine used in the F-111. New lightweight materials and improved design promised more efficient compressor stage-loading and higher turbine temperatures. Generally, military specifications called for the new engine to develop more than 20,000 pounds thrust and have a 9:1 thrust-to-weight ratio. It featured a 22:1 pressure ratio in only 10 stages, whereas, by comparison, the J79 (F-4 aircraft engine) had an overall 14:1 ratio involving 17 compressor stages.

From the start of the engine project, the Air Force and Navy disagreed about its management. In early 1968 the Air Force proposed establishing within one service a Joint Engine-Program Office

BELOW: ***During the F-15's flight test programme the second prototype, 71-0281 was used to test the YF100 engines.*** *US Air Force*

(JEPO) run according to its management procedures and subject only to change for operational and logistical requirements of the other service. This proposal, reflecting the Air Force's single-management concept for the F-15 program, had precedent in other joint projects such as the Navy's purchase of Air Force J79 engines for its F-4s. On the other hand, the Navy favoured single-source procurement and creation of a Joint Executive Committee to oversee separate project offices in each service. The Air Force rejected this proposal, fearing that it would produce divergent engine configurations without yielding the desired cost savings.

The situation reached an impasse, with neither side willing to budge from its position. At one point in this stalemate, Air Force and Navy officials convened a meeting where they simply read their respective position statements and then left without discussing their differences. The issue was partially resolved in April 1968, when Dr Foster named the Air Force executive agent to manage the Initial Engine Development Program (IEDP), but he left open his decision on management of the final development phase. Dr Foster also sought to retain for OSD final source selection authority, but the services were able to persuade him to delegate this authority to them.

On April 8, 1968, requests for proposal were sent to General Electric, Pratt & Whitney, and the Allison Division of General Motors. Revised in July, [illegible] pound thrust engine weighing 2,790 pounds and having a 'common core' gas generator interchangeable with the Navy's F-14 engine. At the end of August, OSD authorised the award of two 18-month contracts totalling $117.45m to General Electric and Pratt & Whitney. The Air Force contract was a composite cost-plus and fixed-type arrangement similar to that for the F-15 airframe, except for a different set of fees and ceiling prices. The Navy's contract, on the other hand, specified fixed prices for both the development and production phases.

Jointly funded by the Air Force and Navy, the contracts authorised each company to build two prototype engines – one for each service. The purpose was not merely to develop different engines, but to fulfil each service's thrust requirements. Since the Navy's proposed aircraft was heavier than the F-15, it required a larger engine. Although both the Air Force and Navy engine models were to be designed, only one of the models would actually be built. However, since the Navy planned to use the TF30 engine in its F-14 prototype, the services agreed that only the Air Force engine model and some components of the Navy model would be built initially. Later, though, both General Electric and Pratt & Whitney invested their own funds to build the Navy's engine model as well.

In November 1968, the plan for a joint engine programme appeared to flounder when the Air Force and Navy announced they would conduct separate contracting and funding arrangements at the end of the initial engine development phase. Dr Foster, however, wished to retain one service as the project manager, at least until both services' engine models met their Military Qualification Test (MQT). Accepting his ruling, the Air Force and Navy agreed to proceed as before but postponed submitting an engine development plan for the remaining phases of the programme. Although they appreciated and endorsed the advantages of a joint effort, the Air Force and Navy preferred to await further definition of the F-X and VFX airframe designs before making a commitment.

Source Selection

Meanwhile, the Air Force and Navy agreed to share source selection authority for the engine. General Goldsworthy, the ASD commander (and his successor, Major General Lee Gossick), represented the Air Force with Admiral J. T. Walker, Naval Air Systems Commander, being his Navy counterpart. Both parties agreed that in the event of conflict between engine and airframe selections, authority would revert to the service secretaries. A similar arrangement governed the source selection board and council, with Air Force and Navy personnel serving as co-chairmen for the two groups.

Even with initial engine source selection under way, the services continued to ignore programme management during the final phase. Dr

BELOW: F-15A 71-0281 during an engine test flight from Edwards Air Force Base in late 1972. US Air Force

ABOVE: ***Fourth prototype F-15A 71-0284 was used for weapons testing and was the first aircraft fitted with the 20mm M61 cannon. Note the high-speed camera fitted to the aft underside of the fuselage.*** *US Air Force*

Foster did not forget and in August 1969 he warned the R&D secretaries that unless they submitted an acceptable management plan by the engine qualification test date, OSD would reassume source selection authority.

Despite this deadline, the two services continued to disagree. The Air Force argued that changing the JEPO arrangement would disturb the F-15 programme whereas the Navy insisted on having 'plant cognizance' [having management authority] if Pratt & Whitney won the engine contract. With each side claiming its approach was the more economical and efficient one, the issue festered until October 1969, when both asked Secretary Packard for a ruling. Some two months later he advised the service secretaries that the Air Force would continue as lead service for the engine development, threatening to take back selection authority if they were unable to choose a winner. General Ferguson and Admiral I. J. Gallantin, Chief of Naval Materiel Command, finally resolved the issue by negotiating an Air Force-Navy agreement to continue the JEPO under the F-15 office and to have General Bellis respond to the naval materiel command chief on F-14 matters and to AFSC on the F-15.

Earlier, in June and July 1969, the two engine contractors submitted technical and cost proposals. The Source Selection Evaluation Board began its study of them on July 7, but did not complete the task until January 30, 1970, because the contractors were late submitting their design substantiation data. In February 1970, after reviewing this data, the board designated the Pratt & Whitney design as 'clearly superior to the General Electric System'. After the Source Selection authority (Secretary Seamans) also chose Pratt & Whitney, that company received the formal award on March 1, 1970 authorising the Air Force and Navy to sign separate engine contracts with it.

The Air Force engine model, designated the F100-PW-100, was an augmented twin-spool, axial-flow gas turbine that delivered more than 22,000 pounds thrust and weighed less than 2,800 pounds. The Navy version of the ATE - the F401-PW-400 - used the same 'common core' as the F100, including common compressors, a smokeless annular combustor, and two high-pressure stages. The two engines differed in the fan, afterburner, and compressor sections. The addition, in the Navy model a stub compressor in front of the main compressor increased engine airflow but, by raising its weight, lowered the engine thrustto-weight ratio. The F401 generated over 27,000 pounds of thrust and weighed under 3,500 pounds.

In January 1969, the Navy changed the size of its engine because the F-14B (formerly VFX-2) would be larger than planned. Although the change increased the difference between the F-15 and F-14 engines, the common core approach remained intact and did not affect costs. The Navy's change required increased airflow to raise thrust from 25,000 to 27,100 pounds for the GE version and from 26,000 to 28,160 pounds for P&W's design. GE's solution was to raise the fan bypass ratio, whereas P&W added a stub stage to the fan to supercharge the common core.

Developing the Advanced Technology Engine was the main problem in an otherwise exemplary F-15 program. In November 1970, because of F-14 funding cuts, the Navy pared its engine request from 179 to 69 units in FY1972 through 1974. Since the larger number of engines set the original cost, this cut required a new formula with a higher price per engine for the Air Force. In the spring of 1971, the Navy further cut its order to 58 engines to fit the lagging F-14B airframe schedule. Then, on June 22, a new Navy decision to buy 301 F-14A's (the model that used the TF30 engine) cancelled the remaining 58 engines and voided the joint Navy-Air Force engine production contract.

Earlier, in February 1971, Pratt & Whitney projected a $65m cost overrun in the engine funding for FY1973.

Although the JEPO stood fast then, advising the contractor that no more funds were available, these new circumstances forced the Air Force to rewrite its own engine production contract. The new agreement raised Air Force costs by about $532m. Under this revised programme, development milestones for the F401 engine slipped from February to December for the Preliminary Flight Rating Test, from February to June 1973 for the military qualification test and from June 1972 to mid-1974 for the delivery of production models.

The Advanced Technology Engine also suffered from several technical problems. At the start of the development programme, there were two compressor designs: the primary aerodynamic compressor Series I engine, and the advanced aerodynamic compressor Series II. In October 1970 both services favoured Series I because it was lighter and on schedule. However, by mid-1971, when it appeared that the Series I version would not meet its full production requirements, the services revived Series II. The Air Force eventually installed Series I in its first five test aircraft and Series II in all remaining test aircraft and in its F-15 production models.

In February 1972, the YF100 (Series I) engine passed its PFRT milestone on schedule, in time for the F-15's first flight in July. The Air Force rated Series I superior in thrust-to-weight, fuel consumption pressure ratio per stage, and turbine temperature levels. Meanwhile, in August 1972, the Air Force suspended MQT testing three times for the Series II engine - an early

warning of the many engine troubles to come in 1973.

Radar and Armament

The F-15's remaining subsystems were open to competitive development. After soliciting industry bids on August 8, 1968, the Air Force selected Westinghouse Electric and Hughes Aircraft in November to develop, produce, and test models of the attack radar subsystem.

McDonnell-Douglas, the airframe contractor, was responsible for selecting the winner of the 20-month competition after flight testing and evaluating both radar prototypes. The Air Force wanted a lightweight, highly reliable advanced design suitable for one-man operation. The radar's capabilities were to include long-range detection and tracking of small, high-speed objects approaching from upper altitudes down to 'tree-top' level. The radar was to send tracking data to a central on-board computer for accurate launching of the aircraft's missiles. For close in dogfights, the radar was to acquire targets automatically on the head-up display so that the pilot would not have to do this task manually. In July and August 1970. McDonnell-Douglas conducted more than 100 flights to test competing radar units aboard its modified RB-66 aircraft. With Air Force approval, McDonnell awarded Hughes Aircraft the radar contract in September.

To cut costs, the Air Force ordered another thorough 'scrub down' of the F-15 requirements. Starting in July 1970, a panel headed by Major General Jewell Maxwell reviewed the avionics and armaments, focusing on three items: (1) the Tactical Electronic Warning System (TEWS), whose development cost the panel favoured separating from the F-15 programme; (2) Target Identification Sensor-Electronic Optical (TISEO), a device for target identification beyond visual range; and (3) the AIM-7-E2-missile, a backup for the AIM-7F Sparrow. The Air Force adopted the panel's recommendation to eliminate the last two systems.

The F-15's armament included both missiles and an internal cannon. The Air Force added the gun on the advice of veteran pilots and Vietnam returnees as well in light of the Israeli success [a 54-0 air-to-air victory over Arab fighters] with cannon in the Six-Day War during June 1967. Though the primary gun for the F-15 was the M61 Vulcan (a 20mm Gatling type cannon used in Vietnam), the Air Force also began a long term project to develop a 25mm cannon using caseless ammunition. In the spring of 1968, it selected Philco-Ford and General Electric to design a prototype of the advanced gun designated the GAU-7A Improved Aerial Gun System [with greater velocity and projectile weight].

ABOVE: ***A great image of the first F-15A prototype 71-0280 seen over the Edwards Air Force Base test range.*** *US Air Force*

The $36m fixed-price competition ended in November 1971, when Philco-Ford won the contract.

The Air Force also proposed to equip the F-15 with a new short-range missile (SRM) for use against manoeuvring fighters at close range. In March 1970, the Air Force selected three contractors - Philco-Ford, Hughes Aircraft, and General Dynamics - to begin competitive prototype development. Six months later, however, the Air Force cancelled the SRM because of rising costs, agreeing with the Navy to substitute an improved version of the Sidewinder missile.

"In May 1968, General McConnell assigned top priority to the F-X program and designated January 1, 1969, as the target date for implementing contract definition. "

Dissent and Decision

Despite USAF attempts to stem criticism of the F-15, basic differences arose within and outside the Pentagon over the kind of aircraft to acquire. The Air Force was especially sensitive to criticism because of competition with the Navy to get funds for an air superiority fighter. Having established the F-15's basic requirements, the Air Force decided to 'speak with one voice' and not tolerate any dissent. Nevertheless, criticism of the F-15 made the Air Force re-examine the project and design an aircraft markedly superior to the one it had promoted at the beginning of the program.

F-XX

One proposed alternative to the F-15, dubbed the F-XX, was the brainchild of Pierre Sprey of Systems Analysis. He believed that ASD engineers, responding to TAC's exorbitant requirements and paying little heed to cost, had produced a design that was too expensive, incorporated high-risk technology, was unnecessarily complex, and would not achieve its advertised air superiority performance. Sprey's alternative was a 25,000-pound, single-seat, one-engine fighter with a high thrust-to-weight ratio and an estimated 25% more range than the F-X. The F-XX was to be specifically designed for combat in the subsonic-transonic region, employing a fixed-wing planform with 60 pounds/square foot wing loading. It would carry a light internal gun and two AIM-9 Sidewinder missiles. Sprey's F-XX proposal shunned complex avionics, featuring instead a simple visual radar, easy and inexpensive maintenance, and a unit cost of only $2m. Sprey favoured prototype development similar to Kelly Johnson's Skunk Works approach in building the SR-71. This alternative also included a VFXX substitute for the Navy's F-14.

The Air Force and Navy were not impressed. They rejected the proposed lightweight fighter because it lacked range for missions deep in enemy territory and could not carry the requisite avionics for countering enemy defences. The services cited the short, unhappy experience of the F-104 as an example of the inadequacy of lightweight fighters. After enemy SAMs downed two F-104s on an escort mission over North Vietnam in 1966, the Air Force hastily withdrew the aircraft from further combat. Finally, the services argued that only the F-15 and F-14 could counter the Soviet high-speed, high-altitude Foxbat interceptor.

But Sprey was not alone in advocating a lightweight fighter, indeed, many veteran Air Force fighter pilots facetiously recommended that the best solution to the air superiority problem was to 'buy MIG-21's'. Simulations and flight tests during 1968 (Feather Duster and Have Doughnut) demonstrated the superior manoeuvrability of

RIGHT: ***Early production-standard F-15A Eagle 73-0112 mounted upside down on a pedestal at the Rome Air Development Center's Newport test site, part of Griffiss Air Force Base, New York. The photo was taken during evaluation of a radar warning system pod mounted on the fuselage in comparison with the aircraft's onboard radar warning system.*** *US Air Force*

lightweight fighters. Several members of the Air Staff aided by dissident Navy fliers, designed a lightweight fighter alternative to the F-15 and, in August 1969, submitted their proposal to General Ryan. Suppressing the proposal, F-15 advocates used the episode to unify the Air Force position on the air superiority fighter.

As later events showed, Sprey's F-XX idea, though having considerable merit, was ill-timed. His criticism only united the Air Force and Navy against him because they were too far along in their advocacy to turn back to the 'drawing board'. Neither wanted to relinquish the field to the other. Although by no means the last challenge to the F-15 and F-14 programs, it set the stage for their defence. A critical factor here was OSD's inflexibility on the tactical Air Force structure. Because they could not shake OSD force size limits, both services preferred to develop aircraft that were as versatile as possible.

The F-15 design also came under fire from Dr Richard Garwin, chairman of the President's Science Advisory Committee (PSAC) Aircraft Panel. Citing the numerical superiority of Soviet fighters, Dr Garwin criticised the abandonment of such promising innovations as the helmet-mounted sight and the trainable gun because he believed their absence placed the F-15 in an unfavourable 'exchange ratio' against enemy aircraft. In replying for OSD, Dr Foster justified the F-15 design by restating the various elements that determined air superiority, including 'pilot skill, aircraft handling qualities, multiple-aircraft and single-aircraft tactics, fuel load, weapons, avionics, command and control equipment, and procedures'. Similarly, he justified development of separate Air Force and Navy aircraft because of 'the unique needs of each service'.

F-15 vs Foxbat and the F-14

In urging development of the F-15, the Air Force was pressed to explain the aircraft's alleged inferiority' to the Soviet Foxbat. Industry sources claimed the F-15 could not defeat the high-speed, high-altitude Foxbat (Mach 3+ at 80,000 ft) and urged scrapping the F-15 programme. General Rhodarmer's team however, convinced congress that, in terms of manoeuvrability, the F-15 was superior to any existing or projected Soviet aircraft. They noted its superior manoeuvrability in air combat, emphasising the F-15's decided edge in such key dogfight factors as wing loading and thrust-to-weight ratio.

Criticism of the F-15 prodded the Air Force to look at other aircraft. It established a joint flight-test programme with the National Aeronautics and Space Administration (NASA) to experiment with the YF-12 - a high-speed, high-altitude fighter developed by Kelly Johnson of Lockheed. The Air Force also funded Mr Johnson to study an advanced tactical fighter combining the speed advantages of the YF-12 and the F-15's superior manoeuvrability. Eventually, the Air Force concluded that the cost of developing such an aircraft would be prohibitive and that the F-15's manoeuvrability, radar, and 'shoot-up' Sparrow missiles could defeat the Foxbat. Describing the Foxbat as a technological threat only, the Air Force remained convinced of the F-15 's ability to 'out-fly, out-fight, and out-fox the rest'.

In authorising development of the next generation tactical fighters, OSD generally presented the F-15 and F-14 as non-competitive aircraft. It saw the F-14 providing the Navy with a long-range missile capability (AWG-9 Phoenix) for fleet air defence and the F-14 variants performing 'other fighter roles', whereas the F-15 was to achieve overall air superiority. When congressmen asked the inevitable question as to which of the two aircraft would win in a dogfight, neither the Navy nor the Air Force was hesitant to advance its own candidate.

However, in the spring of 1969, General McConnell and Admiral Thomas Moore, Chief of Naval Operations, agreed to toe the OSD line, that the two aircraft were intended for different missions. Whenever the issue did arise, the Air Force highlighted the F-15 's manoeuvrability advantage and the mission differences between it and the F-14.

Modifications and First Flight

Criticism of the F-15's design assumptions, though viewed as a threat by some military officials, actually produced distinct advantages. These challenges obliged the Air Force to re-examine the aircraft's design more critically and 'scrub out' extraneous requirements. In particular, NASA's role as a consultant during the source selection and its independent laboratory evaluation uncovered certain deficiencies that might otherwise have gone unnoticed. For example, NASA found the F-15's subsonic drag level was higher than reported. To correct this problem, designers removed the ventral fins and enlarged the vertical fin. General Bellis, testifying in the spring of 1971 before the Senate Armed Services Committee, discussed the major design

US Air Force

US Air Force

changes in the F-15 since its contract award: "The radome has been made more symmetrical to enhance the radar performance. Cowl fences have been added to the upper outer edge of the inlet to improve directional stability. The inlets have been refined. The bluntness of the cowl lip has been changed... The wing and horizontal tail were both moved five inches... to improve aircraft balance and maintain the desired handling qualities and stability... To improve the external aerodynamics, the aft section of the aircraft has undergone some refinement; this includes modified lines, ventral removal, and increased vertical tail height."

On June 26, 1972, the F-15 made its ceremonial debut at McDonnell-Douglas' St Louis plant. Appropriately painted in 'air superiority blue' and christened the Eagle, it was hailed as America's first air superiority fighter since the F-86 appeared some 20 years earlier.

The F-15's first flight occurred on July 27 when Irving Burrows of McDonnell-Douglas piloted the fighter on a 50-minute maiden flight over Edwards Air Force Base, California. All systems 'worked as expected', and the Eagle attained 12,000 feet and about 320 miles per hour. This event also launched the F-15's flight-test programme, which continued on schedule without any significant problems through its 1,000th flight in November 1973. By that date, the F-15 had flown above 60,000 feet at speeds over Mach 2.3.

The flight-test programme, perhaps the most rigorous one ever conducted in American aviation, included wind-tunnel, structural-materials, and flight-simulation tests. Category I testing by the contractor involved 12 aircraft instrumented for specific flights. For example, the No. 1 prototype tested the aircraft's stability and control characteristics, aerodynamic parameters, and provided a 'quick look' at the YF100 pre-production engines and overall aircraft performance.

Prototypes 13 through 20 were designated for Air Force use in Category II testing. The Air Force and McDonnell-Douglas also shared test time on five of the first 12 prototypes. Flight testing took place at three locations - Edwards Air Force Base, Eglin Air Force Base, Florida, and the McDonnell-Douglas airfield in St. Louis, Missouri. The test team at Edwards included seven TAC pilots and six ASD pilots. Wind tunnel tests occurred at Arnold Engineering Development Center near Tullahoma, Tennessee.

NASA supported the F-15 flight-test programme by evaluating three-eighths scale models of remotely piloted research vehicles (RPRVs). The aluminium and fibreglass RPRV's, 23.8 feet long with 16-foot wingspans and weighing 2,000 pounds, were dropped from B-52 aircraft at 45,000 feet and 175 knots. These trials provided invaluable data that enhanced the safety of the full-scale tests later.

That Central Bird

Although priding itself on not being tied to any particular operational doctrine, the Air Force owed its very existence to the principle of centralised control of air resources by a separate service commander. This doctrine's chief value lay in its 'inherent flexibility' to exploit the combat situation while managing air resources economically. Given no cost limits and a reduced tactical force structure, the Air Force predictably selected multi-purpose rather than specialised aircraft.

Inflation and the war in Southeast Asia, however, paved the way for low-cost, specialised aircraft. Accordingly, in October 1965 the Air Force moved to acquire A-7s for close air support until it could develop its own A-X candidate for this mission. Besides satisfying OSD's penchant for commonality and averting forfeiture of the close air support role to the army, this stratagem helped the Air Force to make a case for replacing its aging F-4 fleet by the mid-1970s. Indeed, the Air Force's advanced tactical fighter concept - the F-X - began life as the best combination of air-to-ground and air-to-air capabilities. These features plus its STOL capability won the F-15 initial funding support for design studies.

However, because diverse interests within the Air Force wanted to stamp their particular imprint upon the aircraft, the F-15 emerged as an over compromised design that stood little chance of gaining approval. In addition, the Air Force - faced with keen competition from the Navy for funds - had to overcome Systems Analysis' campaign to replace tactical air's inventory of large, sophisticated aircraft with smaller, less costly ones.

In a masterful stroke in the spring of 1968, the Air Force adopted air superiority - the sine qua none of aerial combat - as the best way out of its dilemma. South Vietnam's 'permissive environment', the Air Force argued, had lulled OSD into pursuing the mistaken policy of 'assuming' air superiority in weapon system development. But the air war over North Vietnam had already shown that even older MIGs could outclass sophisticated but less manoeuvrable American fighters. Only by hurriedly installing an aerial gun in the F-4 did USAF manage to keep an air-combat edge. Furthermore, the Air Force emphasised the folly of assuming air superiority over Europe - a region of more vital concern to the United States. The Moscow Air Show in July 1967 forcefully brought this point home when the Soviets paraded a half-dozen new fighters for Americans to evaluate and contend with in the years ahead.

In the summer of 1968, the Air Force rallied behind a new slogan: 'To fly and fight'. It applied a 40,000-pound weight limit on the F-15 and pointed the design toward an uncompromised air superiority fighter. Significantly, the design yielded a bountiful 'fallout' capability. Thus, at little extra cost, the F-15 could carry enough fuel, armaments, and avionics to perform a host of air-to-ground missions as well. In short, the Air Force advertised air superiority, while in fact developing a worthy successor to the F-4. The F-15 became 'that central bird' the Air Force needed for flexibility under its centralised control doctrine.

Approval of the F-15 gave the Air Force the luxury of considering specialised aircraft, provided OSD relaxed its stringent force structure ceilings. The A-X (A-10) was ready for procurement to provide close air support, while a low-cost, lightweight fighter (the YF-16 and the YF-17) was undergoing prototyping for the air superiority mission.

F-15 Eagle AMERICA'S AIR SUPERIORITY FIGHTER

Details of the F-15A and F-15B and the F-15C and F-15D Eagle fighters come from official US Air Force flight manuals. **Mark Ayton** provides edited versions.

The F-15 is a high-performance, supersonic, all-weather air-superiority fighter built by McDonnell Aircraft Company. Its primary mission is aerial combat, but it can also perform ground attack missions. Radar and heat seeking air-to-air missiles and a 20mm gun are the primary armament. The aircraft is powered by two Pratt & Whitney F100 turbofan engines which provide a high thrust to weight ratio.

Aircraft appearance is characterised by a high-mounted swept-back wing, twin vertical stabilisers, and a light, high strength structure containing rugged subsystems. The cockpit is elevated to enhance visibility.

The major aircraft systems are designed and located for high maintainability and reliability. An airframe mounted accessory drive (AMAD) contains many accessories previously mounted on the engine. A jet fuel starter provides self-starting of the engines. System design precludes the requirement for batteries.

ABOVE: ***One of the earliest F-15A aircraft built, serial number 73-0098 assigned to the Louisiana Air National Guard's 122nd Tactical Fighter Squadron seen landing at Luke Air Force Base in March 1991.*** *Dan Stijovich*

F-15A EAGLE

ENGINES

The F-15A aircraft is powered by two Pratt & Whitney F100-PW-100 turbofan engines with afterburners. A self-contained jet fuel starter is used to crank the engines for starting and external power is not required during engine starting.

Engine Air Induction System

The two independent air induction systems consist of three variable ramps, a variable diffuser ramp, and a variable bypass door.

Variable ramps provide air, at optimum subsonic flow, to the face of the engine fan inlet throughout a wide range of aircraft speeds. Ramp position is controlled by the air inlet controller.

The bypass door automatically controls the Mach number position in the inlet duct. The air inlet controller positions the bypass door.

An air inlet controller (AIC), one for each inlet, uses angle of attack, aircraft Mach number and other air data system outputs to automatically schedule the ramps and bypass door throughout the aircraft envelope. The first ramp is locked in the up position until the engine is started. The diffuser ramp remains locked in the up position until the aircraft accelerates above Mach 0.5.

Engine Oil System

Each engine is equipped with a completely self-contained oil system. Oil is supplied to the main pump element by gravity feed.

SYSTEMS

Aircraft Fuel System

The fuel feed systems are independent and are identical except for the jet fuel starter supply from the right engine feed line.

The unified control (UC) performs the following functions: It provides engine speed control, schedules rear compressor variable vanes, initiates engine and afterburner fuel flow, controls the convergent exhaust

BELOW: ***Based at Luke Air Force Base, Arizona, the 405th Tactical Training Wing was the F-15 Replacement Training Unit. One of its four assigned units was the 550th Tactical Fighter Training Squadron. F-15A 76-0106 assigned to the 550th is seen on take-off from March Air Force Base in January 1986.*** *Dan Stijovich*

nozzles, provides cooling fuel for the engine electronic control, and provides a positive fuel cut-off at engine shutdown. The unified control is scheduled mechanically from IDLE to MIL power but is scheduled by the engine electronic control at MIL power and above.

The engine electronic control (EEC) contains operating schedules for the variable fan inlet vanes and divergent exhaust nozzles. During operation at and above MIL power the EEC regulates engine fuel to control fan turbine inlet temperature and provides supervisory trimming of the unified control to maintain engine operation at maximum safe power. The EEC senses compressor speed, fan turbine inlet temperature and fan speed. It compares these values to its operating schedule and, if required, trims the unified control to maintain optimum engine operation.

Ignition System
Fuel Transfer

The fuel transfer system is completely automatic and provides automatic backup gravity transfer if normal transfer fails. It also ensures full feed tanks for all engine power settings, and automatic external fuel transfer sequencing. Normal fuel transfer is accomplished by three electric transfer pumps and engine bleed air pressure. The pumps automatically transfer fuel to the engine feed tanks when the transfer level control valves in these two tanks drop to a specified level. The transfer pumps run continuously when electrical power is applied to the aircraft and an engine master switch is ON. If the electrical transfer pumps fail, all internal fuel will transfer (through gravity feed lines) to the engine feed tanks. External fuel is transferred by engine bleed air pressure. If a complete electrical failure occurs, the drop tanks will still transfer.

Fuel Feed System

There are two separate fuel feed systems, one for each engine. During normal operation, the right boost pump supplies fuel to the right engine only and the left boost pump supplies fuel to the left engine only. The boost pumps are capable of supplying the engine with fuel during all flight attitudes. If one boost pump fails, the emergency boost pump is activated, the interconnect valve associated with the failed boost pump opens, and the cross-feed valve opens. With the interconnect valve open, fuel will gravity feed into the feed tank with the operating boost pump. The operating boost pump and the emergency boost pump then supply fuel to both engines through the cross-feed valve. If both boost pumps fail, the emergency pump is activated, both interconnect valves open and fuel will gravity feed between feed tanks. The emergency boost pump then supplies fuel to both engines through the cross-feed valve. If both boost pumps and the emergency boost pumps fail, fuel is supplied to the engines through the separate fuel feed lines by gravity and suction flow. Baffles in the feed tanks provide a limited fuel supply for the left and right boost pumps during negative G or inverted flight. The heat exchangers in each feed system provide cooling for the aircraft-mounted accessory drive, integrated drive generator, power control hydraulic system and utility hydraulic systems. If the fuel is too hot, a thermally operated bypass valve on the heat exchanger opens and bypasses fuel back to the wing tanks after going through the heat exchanger. The wing tanks act as a heat exchanger to lower the fuel temperature.

Fuel Tank Pressurisation and Vent

The pressurisation and vent system provides regulated engine bleed air pressure to all internal and external tanks for pressurisation, and to the external tanks for fuel transfer. The system also provides pressure relief of the fuel tanks during climbs, and vacuum relief of the fuel tanks, as required, during descents. The tanks do not pressurise until the weight is off the landing gear and terminates as soon as the left main gear is compressed at touchdown.

Fuel Quantity Indicating System

The fuel quantity indication system provides readings, in pounds, of usable internal and external fuel. The system components include the fuel quantity indicator, a built-in-test, a BINGO light, and an independent FUEL LOW light.

Air Refuelling System

The air refuelling system has a fixed receptacle, a control switch, a hydraulically operated slipway door, two slipway lights, a receptacle flood-light, a signal amplifier, a READY light, an air refuelling release button, an air refuel pressure switch and an emergency slipway door actuating system. Normal operation is accomplished by placing the slipway control switch to OPEN; the slipway door opens, and the signal amplifier conditions the fuel system circuitry to receive fuel. Once the slipway door is fully open the slipway lights, the receptacle floodlight, and READY light (aircraft is ready for refuelling) comes on. When the boom is locked in the receptacle the READY light goes out, the tanker director lights come on, and fuel is transferred at a rate up to approximately 3,900 pounds per minute without external tanks or approximately 1,000 pounds per minute with external tanks. Boom locking also energises the automatic (flight outside the boom envelope) and manual (tanker initiated) disengage capabilities. The air refuel pressure switch, in the receptacle outlet, automatically disengages the boom if refuelling pressure becomes too great. If the boom becomes

BELOW: *The 49th Tactical Fighter Wing based at Holloman Air Force Base, New Mexico had three F-15-equipped fighter squadrons assigned: the 7th, 8th, and 9th Tactical Fighter Squadrons. This jet, F-15A 76-0114/HO from the 9th TFS is seen at Nellis Air Force Base, Nevada in March 1991. Dan Stijovich*

ABOVE: ***Georgia Air National Guard's 128th Tactical Fighter Squadron based at Dobbins Air Reserve Base flew the F-15 between 1986 and 1996. F-15A 75-0071 is seen at Nellis Air Force Base, Nevada in July 1989.*** Dan Stijovich

disengaged, the READY light comes on (after a five second delay) indicating fuel transfer is interrupted and the system has been automatically recycled for a new hook-up. At the completion of the air refuelling sequence, the boom is disconnected by pressing the air refuelling release button (auto acquisition button).

Electrical Power Supply System

The electrical power supply system consists of two main AC generators, two transformer-rectifiers, an emergency AC/DC generator, and a power distribution (bus) system.

External electrical power can be applied to the bus system on the ground, and the JFS generator provides electrical power to part of the bus system during an engine start without external power.

Hydraulic Power Supply System

Hydraulic power is supplied by three separate systems with each system divided into two or more circuits. Reservoir level sensing (RLS) is employed in all three systems for the purpose of isolating a leak. When a leak develops in a circuit, a valve senses the reservoir level and shuts off the affected loop. Through this method the maximum number of circuits remain operable. The hydraulic system also employs return pressure sensing (RPS). RPS prevents flow through a selector valve if a leak should develop in a subsystem downstream of the selector valve.

Bleed Air System

The bleed air system supplies air to the ECS and fuel pressurisation system. The flow, temperature and pressurisation of the bleed air is initiated and regulated by the requirements of each system. A rotary switch provides selection of bleed air from one or both engines or shuts all bleed air off.

Landing Gear System

The gear is electrically controlled and hydraulically operated. While weight is on the gear, the gear cannot be retracted. When the main and nose gears are extended, the forward door(s) will be closed.

Nose Gear Steering System

The nose gear steering system is a continuous operation, dual mode system. It is electrically controlled by two switches located on the control stick and hydromechanically operated through inputs from the rudder pedals. The system is automatically engaged when the nose gear strut is compressed. The dual mode feature consists of a normal mode and a manoeuvring mode. In the normal mode, the nosewheel can be turned left, or right 15°.

In the manoeuvring mode, the nosewheel can be turned left or right 45°. The manoeuvring mode is selected by depressing and holding the nose gear steering button located on the control slick. The normal mode can be disengaged by depressing the paddle switch located on the control stick. With the system disengaged, the nose gear becomes free swivelling and may be rotated 360°. When the system is engaged with the nose gear positioned within a range of approximately 45° left or right, the nose gear will return to the position commanded by the rudder pedals. If the nose wheel is outside this range when the system is engaged, rudder pedal inputs will not have any effect. When taxiing is commenced the nose gear will be brought into range through centring action and the pedals will command nose wheel position.

Brake System

The main landing gear wheels are equipped with full powered brakes operated by toe action on the rudder pedals. An anti-skid system is incorporated in the normal system to prevent wheel skid. A touchdown protection circuit (with anti-skid ON) prevent brake application until the main wheels reach a speed of approximately 45 knots.

Flap System

Each wing has a two position trailing edge flap. The flaps are electrically controlled and operated. When the flaps are down, they are protected from structural damage by a blow up airspeed switch. The switch is set to automatically retract the flaps at approximately 250 knots. At approximately 240 knots, the flaps will automatically return to the down position, providing the flap control switch is in the down position.

Speed Brake System

A speed brake is located on the upper surface of the centre fuselage just aft of the canopy. It is electrically controlled and hydraulically operated. The speed brake can be positioned to any intermediate position between fully retracted and fully extended.

Flight Control System

The aircraft's primary flight control surfaces consist of conventional ailerons, twin rudders, and stabilators which are capable of symmetrical or differential movement. The control surfaces are positioned by mechanical and/or control augmentation system (CAS) inputs. Artificial feel systems provide simulated aerodynamic forces to the control stick and rudder pedals.

RIGHT: ***F-15B 77-0162/ LA assigned to the 461st Tactical Fighter Training Squadron based at Luke seen on final approach to March Air Force Base, California in January 1986.*** Dan Stijovich

LEFT: *Between 1985 and 1995, the 57th Fighter Interceptor Squadron based at Naval Air Station Keflavik, Iceland flew the F-15C and F-15D Eagle. Catching some summer sun in July 1992, 57th FIS F-15C 80-0039/IS lands at Nellis during an exercise.* Dan Stijovich

LEFT: *Tigers. The 53rd Fighter Squadron operated the F-15C Eagle at Spangdahlem Air Base, Germany between February 25, 1994, and March 1999. Two of the squadron's F-15Cs are seen at Nellis in April 1996.* Dan Stijovich

The feel systems have trim actuators which, through the power cylinders, move the entire control surfaces. Secondary flight control surfaces are flaps and speed brake.

Automatic Flight Control Systems (AFCS)

The AFCS provides the following functions: pitch, roll and yaw control augmentation; relief autopilot modes of pitch/roll attitude and altitude hold; pitch, roll and yaw trim, and take-off trim.

Control Augmentation System

One function of the AFCS is the Control Augmentation System or CAS. The CAS provides stability and is the primary means of controlling the flight control surfaces. The CAS measures the stick force exerted by the pilot and control surface deflection, compares these, and makes corrections to ensure that control surface deflection matches control stick forces. A dual channel fault monitor automatically turns a CAS axis off if an erroneous signal is supplied to the control surfaces. The mechanical flight control system and the CAS are independent and provide a redundant flight control system, therefore, the aircraft may be flown by either system.

Roll CAS, Pitch CAS and Yaw CAS provide stability and control about the lateral, longitudinal and directional axis, respectively. A failure in the pitch or yaw CAS causes roll CAS to disengage. Operation of each CAS is controlled by the respective three position engage switch on the CAS control panel.

Canopy System

The cockpit area is enclosed by a clamshell type canopy. The main components of the canopy system are a hydraulic actuator which provides manual and powered operation of the canopy, a locking mechanism, and pyrotechnic canopy remover for emergency jettison. Latches on the canopy frame and along the lower edge of the canopy engage fittings on the cockpit sill structure to lock the canopy to the fuselage. An inflatable seal, installed around the edge of the canopy frame, retains cockpit pressure when the canopy is locked. A rain seal is installed outboard of the pressure seal to divert rainwater away from the cockpit.

Ejection Seat System

The IC-7 ejection seat is a fully automatic rocket system that provides the pilot with a quick, safe, and positive means of escape from the aircraft under emergency conditions. The seat includes an initiation system which, among other things, jettisons the canopy before firing the rocket catapult. In addition, the seat includes a seat stabilisation system called the Directional Automatic Realignment of Trajectory (DART) to stabilise the seat during rocket burn. Operation of the seat is divided into two phases: primary and secondary operation. Primary operation of the seat includes all operating events that occur during the ejection sequence. This sequence begins with actuation of the ejection control handle which causes the canopy to jettison and the rocket catapult to fire. It continues until a normal parachute descent of the occupant is accomplished. After the ejection sequence, seat operation is completely automatic and requires no additional action by the occupant during the sequence. Secondary operation of the seat consists of seat height adjustment and controlling shoulder movement.

Environmental Control System

The environmental control system (ECS) provides conditioned air and pressurisation, for the cockpit and avionics, windshield anti-fog and anti-ice, anti-G, canopy seal, and fuel pressurisation. The ECS uses engine bleed air from both engines for normal operation. Cooling for the avionics, with the air source knob OFF, automatically switches to ram air. Also ram air cooling is automatically supplied to the avionics whenever compressor inlet duct pressure drops.

Air Data Computer

The air data computer (ADC) is a digital

RIGHT: ***Between 1987 and 2000, the 54th Fighter Squadron was one of two F-15C-equipped units assigned to the 3rd Wing based at Elmendorf Air Force Base, Alaska. Enjoying a break from the onset of the Alaskan winter at Nellis in November 1989, is 54th TFS F-15C 80-0053/AK.***
Dan Stijovich

computer which receives inputs from the pitot-static system, the AOA probes, the left total temperature probe, the altimeter setting knob, the nose landing gear door switch, and the flap switch. The ADC corrects these inputs for sensor error as required, computes various parameters from this data and furnishes required parameters to aircraft equipment and cockpit displays. In addition, the ADC performs validity checks on critical data as received by the equipment or display and will actuate appropriate caution lights or warning flags if the data is determined to be invalid. Operation of the ADC is entirely automatic and no controls are available to the pilot.

Central Computer

The central computer (CC) is a high speed, stored program, general purpose digital computer that performs mission oriented computation from data received from control panels and subsystems aboard the aircraft. The computations include air-to-air and air-to-ground steering and weapon delivery, navigation, flight director, and control and display management. The CC provides the pilot with steering and weapon delivery cues, target data, avionic system status, weapons configuration and flight data in the air-to-air attack, air-to-ground attack, visual identification (VI), and attitude director indicator (ADI) modes of operation. The CC computations are controlled by the operational flight program stored in the CC memory. Upon application of aircraft power, the computer is operational. Failure detection of the peripheral systems and CC internal operation is done by continual monitoring. Back-up system substitution is also accomplished in the central computer. If the computer detects a power loss or failure, the CC light on the built-in-test (BIT) panel, and audio-visual BIT light on the caution light panel will come on steady.

Navigation Head-Up Displays (HUD)

The HUD, on the main instrument panel, displays the following aircraft parameters in all modes of the avionics system: magnetic heading, indicated airspeed, barometric altitude, velocity vector, flight path, and pitch and roll. In all modes the beading, airspeed and altitude symbology can be removed by placing the HUD symbol switch, on the HUD control panel, to the reject position. In addition to the flight parameters, the HUD displays navigational data if the avionics system is in the attitude director indicator (ADI) mode.

In navigation (NAV) mode, in addition to the flight parameters, the HUD displays bank steering to the destination selected, distance to destination, steering mode selected, and nav destination selected.

In TACAN (TCN) mode, the HUD displays are the same as in NAV mode except that the bank steering displayed is to the selected tacan radial, the distance displayed is to the tacan station, and destination is not displayed.

In ILS/NAV and ILS/TCN (instrument landing set) modes, in addition to the flight parameter, the HUD displays the following: bank and pitch steering bars for approach and landing on runway destination, distance to destination (in ILS/NAV), or tacan station (in ILS/TCN), and the discrete of the steering mode selected.

Time-to-go is displayed to the nearest minute with a maximum reading of 999 minutes. When the gear is down, in ADI mode, angle-of-attack data in cockpit units is displayed on the HUD.

TF-15 later F-15B Trainer Fighter Version

The TF-15 aircraft is a tandem configured aircraft which performs

BELOW: ***Between 1983 and 2010, the 325th Fighter Wing based at Tyndall Air Force Base, Florida served as the F-15 Replacement Training Unit. Tyndall-based F-15C 80-0038/TY assigned to the 2nd Fighter Squadron is seen at Nellis in January 1996.***
Dan Stijovich

the secondary role of a trainer without compromising its primary role of an all-weather air superiority fighter.

The front cockpit of the two-seater is identical to the single-seat cockpit except that an intercom system is added, and the oxygen quantity gauge registers 10 litres. The rear cockpit contains the same equipment as the forward cockpit with a few differences:

The main communication control panel operates and functions the same as the main F-15A communication control panel in the front cockpit, except the mode 3.

The accelerometer measures acceleration G loads. It operates the same but is independent of the front cockpit accelerometer.

Air-to-ground, ADI, and VI mode advisory lights in the rear cockpit indicate what mode the pilot in the front cockpit has selected.

Dual Seat Operation

A command selector valve is provided in the rear cockpit to select the desired ejection sequence to be initiated from the rear cockpit or provide for single ejection for solo flight.

GENERAL FLIGHT CHARACTERISTICS

Any discussion of flight characteristics must include a description of the night control system since its operation modifies the inherent handling qualities of the aircraft. The pilot must understand the way that loss of various portions of the system will affect the handling qualities.

The aircraft was designed for maximum performance and compromises were made to achieve this performance. The flight control system was designed to negate the undesirable effects of these compromises and provide superior handling qualities and manoeuvrability. While the aircraft is controllable in conservative flight and landing without the aid of various portions of the system, handling qualities will be degraded.

The aircraft has a hydro-mechanical control system with conventional ailerons and twin rudders. A differential stabilator provides both pitch control and, in addition to the ailerons roll control. The relationship between stick force and/or position versus control surface movement is modified by the Control Stick Boost and Pitch Compensator (CSBPC). Superimposed on this hydro-mechanical system is an electrical, dual channel, high authority, three axis Control Augmentation System (CAS) utilised to shape aircraft response to pilot inputs while providing three axis stability augmentation and autopilot functions. Since CAS electrical inputs are applied directly at the actuator, the aircraft is fully controllable with the loss of any or all mechanical linkages with CAS on. In fact, the pilot will not necessarily be aware of loss of mechanical linkages since, with CAS on, control surfaces are positioned by the CAS electrical inputs rather than by the mechanical linkage inputs.

Angle of Attack

Angle of Attack (AOA) is defined as the angle formed by the chord line of the wing and the aircraft flight path (relative wind). AOA in arbitrary units is displayed on the AOA indicator and, with the gear down, on the HUD. The true AOA is displayed on the HUD at all times as the angle between the aircraft symbol and the velocity vector. The relationship between true AOA in degrees and units AOA displayed on the indicator and HUD varies non-linearly with Mach number. At Mach 0.2, 19 units is approximately 10°. At Mach 0.85, eight units is approximately 0.5°.

Handling Qualities

Handling qualities are essentially the same throughout

the flight envelope with the Control Stick Boost and Pitch Compensator (a device which contains the Pitch Ratio Adjust Device, the Pitch Trim Compensator, Roll Ratio Adjust Device, and the Aileron Rudder Interconnect) and CAS operating. With CAS disengaged, only minor differences can

ABOVE: ***F-15A Eagle 76-0078/SL assigned to the 131st Fighter Wing, Missouri Air National Guard flies a training mission over the Missouri countryside.*** *US Air Force/ MSgt Thomas Meneguin*

ABOVE, LEFT: ***Five months after this shot was taken at Nellis in March 1990, the F-15C-equipped 58th Tactical Fighter Squadron based at Eglin Air Force Base, Florida was deployed to King Faisal Air Base, Saudi Arabia in support of Operation Desert Shield and eventually Desert Storm.*** *Dan Stijovich*

LEFT: ***F-15C Eagle 82-0019/ FF with tail markings for the 71st Fighter Squadron commander from Langley Air Force Base, Virginia, flies over the Emerald coast of Florida during exercise Combat Archer, a Weapons System Evaluation Program in May 2002.*** *US Air Force/ TSgt Michael Ammons*

be noted, primarily, in damping. With the CSBPC failed, handling qualities are severely degraded, but the aircraft may be flown sub sonically in conservative flight. If the CSBPC fails, a controllability check should be performed.

Stalls

A stall is defined as the maximum AOA that can be attained with full aft stick.

The 1G stall is characterised by light buffet commencing at 20 units AOA. The buffet increases in intensity up to about 23 units then decreases in intensity as AOA is further increased. Only minor lateral or directional oscillations occur. With the stick on the aft stop, any lateral and/or directional control inputs may be made with no adverse effects. Lateral and directional control inputs forward of the aft stop have not been investigated. The stall stabilises al 85-90 knots with well damped yaw oscillations not exceeding 5° and well damped roll oscillations not exceeding 15°. Longitudinal control is positive and stall recovery is positive when the stick starts forward.

Departures

Departures are more probable with the speed brake extended, in accelerated stalls, and with CAS on. Most departures are dominantly rolling. Recovery is positive with neutral lateral and longitudinal stick. Recovery rolls are usual. Neutral stick position provides maximum aileron deflection. Stagnation of both engines will probably occur.

Spins

A non-oscillatory spin mode has been encountered after a speed brake-out accelerated departure. Spin recovery appears probable from a steady state spin. Full aileron with the spin should be maintained until the AOA is reduced. Maximum aileron is available with neutral longitudinal stick. Stagnation of both engines will probably occur.

MAIDEN FLIGHTS AND PRODUCTION

The F-15A made its maiden flight from Edwards Air Force Base, California on July 27, 1972 followed by the F-15B, also at Edwards on July 7, 1973. McDonnell built 384 single-seat F-15A aircraft between 1972 and 1979, and 61 two-seat F-15Bs during the same period. Operators are the Israeli Air Force and the US Air Force.

F-15A Characteristics

Length	63ft 9in
Wingspan	42ft 9.75in
Height	18ft 5.5in
Tailplane span	28ft 3in
Vertical stabiliser spacing	11ft 3in
Wheel track	8ft 11in
Wheelbase	17ft 9in
Wing area	608ft^2
Empty weight	27,000lb
Max take-off weight	56,000lb
Ceiling	65,000ft
Max speed	Mach 2.5 plus at 45,000ft

F-15C EAGLE

This section lists the engine, engine control, ignition, afterburner, and exhaust nozzle differences of the F-15C/F-15D compared to the original F-15A/F-15B.

ENGINES

F-15C and F-15D aircraft are powered by two Pratt & Whitney F100-PW-220 turbofan engines with afterburners.

The F100-PW-220 engine is controlled by a full authority digital electronic engine control (DEEC). The DEEC automatically trims to maintain performance as the engine deteriorates.

The F100-PW-220 incorporates improvements which provide improved hot section durability/reliability and more responsive/reliable afterburner operation. The most visible difference between the two engines is the F100-PW-220 inlet pressure probe.

A self-contained jet fuel starter is used to crank the engines for starting. External power is not required during engine start.

The F100-PW-220 engine control consists primarily of a hydromechanical main fuel control (MFC), afterburner fuel control (AFC) and a full authority digital electronic engine control (DEEC).

Digital Electronic Engine Control (F100-PW-220)

The digital engine control (DEEC) contains the engine operating schedules for automatic control from IDLE to MAX afterburner power and is powered by the engine alternator. The DEEC schedules engine and afterburner fuel flows, compressor inlet variable vanes (CIVV), rear compressor variable vanes (RCVV), start bleed position, anti-ice, and nozzle position. The DEEC controls engine performance by scheduling engine fuel flow to control airflow and nozzle position to control engine pressure ratio (EPR). EPR is the ratio between engine exhaust pressure and engine inlet pressure. By controlling airflow and EPR the engine performance is maintained consistent for a new or deteriorated engine until the FTIT limit is reached. If the DEEC detects a failure that prevents it from safely controlling the engine it will automatically switch to the secondary mode. In this mode afterburner operation is inhibited, rpm is limited to about 80%, the CIVV are in the fully closed position, and the nozzle is closed to the minimum area (less than 5%). The RCVV, start bleeds and engine fuel flow are scheduled by the main fuel control. The engine will remain in this mode until the failure clears and the engine control switch is cycled.

Engine Monitoring System (F100-PW-220)

The F100-PW-220 engine incorporates an engine monitoring system which consists of the DEEC and the engine diagnostic unit (EDU). The DEEC and EDU continuously monitor electrical control components and engine operation to detect engine failures. Abnormal engine operation and either intermittent or hard failures of components are detected and flagged for maintenance. During abnormal engine operation or component failure, the EDU will record engine and aircraft data as an aid to maintenance troubleshooting. The EDU also maintains engine life cycle information. An airframe mounted GO, NO-GO flag, located on the avionics status panel in the nose wheel well, is tripped if a fault is detected which requires immediate maintenance attention.

Ignition System

In the F100-PW-220 engine, an additional afterburner ignitor is provided, and afterburner [illegible] [illegible] a no-light or blowout, without retarding the throttle to MIL.

Afterburner System

In addition, the F100-PW-220 engine uses a light-off detector (LOD) to signal the DEEC if a light-off occurs. The DEEC then schedules the AFC fuel flow for the remaining segments. If the LOD does not sense a light-off or a blowout occurs, the DEEC automatically resets the MFC to MIL and terminates afterburner fuel flow. A check of the LOD is performed and an afterburner relight is attempted if it checks good. If the LOD is failed, a relight will not be attempted unless the throttle is retarded to MIL and returned to afterburner. Afterburner is inhibited in the ENG CONTR OFF mode.

Exhaust Nozzle Control

The nozzle is controlled by throttle position and landing gear handle position. With the gear handle down, throttle in IDLE, the EEC (F100-PW-100 engine) DEEC (F100-PW-220 engine) on the nozzle will be approximately 80% open. As the throttle is advanced, the nozzle closes to near minimum area. With the landing gear handle up, the nozzle is near minimum area at all times except at MIL power or above. At MIL power the nozzle indicators will show the nozzles slightly open (5-10%), and the F100-PW-100 engine EEC begins trimming the nozzle position. As the throttle is advanced in the afterburner range the nozzles will schedule further open to compensate for increasing afterburner fuel flow. With the EEC (F100-PW-100 engine) off or inoperative or with the DEEC (F100-PW-220 engine) off or in secondary mode, nozzle position will be closed to near the minimum area in flight or on the ground (except when afterburner is selected with the F100-PW-100 engine). This [illegible] result in higher idle thrust and taxi [illegible]

BELOW: *F-15C Eagle 85-0128/MO with tail markings for the 390th Fighter Squadron commander from Mountain Home Air Force Base, Idaho flies over the Gulf of Mexico, during exercise Combat Archer in December 2002.* US Air Force/TSgt Michael Ammons

ABOVE: ***F-15C 79-0022/ BT assigned to the 22nd Tactical Fighter Squadron based at Bitburg Air Base, West Germany over Denmark in August 1986 during Exercise Oksboel.*** *US Air Force/MSgt Patrick Nugent*

RIGHT: ***F-15C 81-0049/ CR assigned to the 32nd Tactical Fighter Squadron based at Soesterberg Air Base, Netherlands carrying live AIM-9 Sidewinder and AIM-7 Sparrow missiles on a Zulu alert mission designed to protect Northern NATO nations from possible attack.*** *US Air Force/SSgt David Nolan*

Aircraft Fuel System

Fuel is carried internally in four interconnected fuselage tanks, and two internal (wet) wing tanks. External fuel is carried in three 600 gallon drop tanks. The external drop tanks, with pylons , are mounted on the centreline and inboard wing stations, and are completely interchangeable.

On F-15C and F-15D aircraft, conformal fuel tanks (CFTs) maybe mounted on the outboard side of each engine nacelle. Each CFT is compartmented and automatically sequences compartment fuel transfer to maintain centre of gravity.

All tanks may be refuelled on the ground through a single pressure refuelling point, airborne they can be refuelled through the aerial refuelling receptacle. External tanks may be individually fuelled through external filler points. The internal wing tanks and tank 1 are transfer tanks.

On F-15C and F-15D aircraft, tank 1 consists of one main tank and a left and right auxiliary tank. The tanks are so arranged that all internal fuel will transfer even if the transfer and boost pumps fail.

Also, on F-15C and F-15D aircraft, CFT fuel is transferred by transfer pumps to any internal tank that will accept it.

Regulated engine bleed air pressure transfers fuel from the external tanks to any internal tank that will accept it. and also provides a positive pressure on all internal tanks.

On F-15A and F-15B aircraft before 1F-15-753, the fuel tanks are not pressurised until the weight is off the wheels. On F-15A and F-15B aircraft after 1F-15-753 and all F-15C and F-15D aircraft, the fuel tanks are not pressurised until the gear handle is UP.

On F-15C and F-15D aircraft, each CFT is pressurised by a self-contained ram air pressurisation and vent system. Float type fuel level control valves control fuel level during refuelling or fuel transfer operations. On F-15C and F-15D aircraft during refuelling, the transfer pump in tank 1 is shut off, causing the interconnect valve between tank 1 and the left auxiliary tank to open and the left and right auxiliary tanks then fill as tank 1 fills.

During transfer, fuel will only gravity transfer to the auxiliary tanks through a standpipe located near the top main tank of tank 1.

All internal, CFT and external fuel (except engine feed tanks) may be dumped overboard from an outlet at the trailing edge of the right wing tip. All internal fuel tanks are vented through the vent outlets in their individual pylons. Each CFT is vented through its vent outlet near the back of the CFT. The fuel quantity indicating system provides fuel quantity in pounds, of all internal, CFT and external fuel.

Engine Anti-Ice System

The engine anti-ice system is comprised of the inlet ice detector and the engine anti-ice valve. The engine anti-ice valve and the inlet ice detector are functionally unrelated. The detector only senses engine inlet ice build-up and illuminates the INLET ICE light. The engine heat switch, on the ECS panel, controls the engine anti-ice airflow to the engine nose cone and stationary inlet guide vanes.

The F100-PW-220 engine, in addition to the anti-ice air to the engine nose cone and stationary inlet guide vanes, electrically heats the inlet pressure probe. The F100-PW-220 engine DEEC will automatically shut off the engine's anti-ice when the altitude is above 30,000 feet or the engine inlet temperature is above 15°C (60°F) regardless of switch position.

MAIDEN FLIGHTS AND PRODUCTION

The F-15C made its maiden flight from Lambert Field, St Louis, Missouri on February 26, 1979 followed by the F-15D, also at Lambert Field on June 19, 1979. McDonnell built 483 single-seat F-15C aircraft between 1979 and 1985, and 92 two-seat F-15Ds during the same period. Operators are the Israeli Air Force, the Royal Saudi Air Force, and the US Air Force.

F-15C Characteristics

Length	63ft 9in
Wingspan	42ft 9.75in
Height	18ft 5.5in
Tailplane span	28ft 3in
Vertical stabiliser spacing	11ft 3in
Wheel track	8ft 11in
Wheelbase	17ft 9in
Wing area	608ft²
Empty weight	28,000lb
Max take-off weight	68,000lb
Ceiling	65,000ft
Max speed Mach 2.5 plus at 45,000ft	Mach 2.5 plus at 45,000ft
Combat radius	870nm unrefuelled
Ferry range with 730 US gal conformal fuel tanks and three external fuel tanks	3,000nm

F-15E Strike Eagle
AMERICA'S MULTI-MISSION BOMBER

Mark Ayton provides edited details of the F-15E Strike Eagle from the official US Air Force flight manual.

The F-15E is a high-performance, supersonic, all-weather, dual role fighter built by McDonnell Douglas Aerospace. In the air superiority role, its primary weapons are radar guided and infrared homing air-to-air missiles and a 20mm gun. In the interdiction role, originally the aircraft carried Low Altitude Navigation Targeting Infrared for Night (LANTIRN) AAQ-14 targeting and AAQ-13 navigation pods on dedicated sensor stations under the left and right engine inlets respectively and can carry a variety of guided and unguided air-to-ground weapons. Since January 2005, the AAQ-14 targeting pod has been replaced by the AAQ-33 Sniper.

Aircraft appearance is characterised by a high mounted swept-back wing and twin vertical stabilisers. The cockpits are elevated to enhance visibility. The basic aircraft configuration is with conformal fuel tanks (CFTs) and without pods or pylons. CFTs with tangential carriage of air-to-air missile and air-to-ground weapons can be removed.

Aircraft systems are designed and located for high maintainability and reliability.

ENGINES

All aircraft through serial number 90-0232 are powered by two Pratt & Whitney F100-PW-220 turbofan engines, and all aircraft from serial number 90-0233 up, are powered by two Pratt & Whitney F100-PW-229 turbofan engines.

All further references will be made using '220 engines' or '229 engines'. The 220 engine is controlled by a full authority digital electronic engine control (DEEC). The 229 engine is controlled by an improved digital electronic engine control (IDEEC). The DEEC/IDEEC automatically trims to maintain performance as the engine deteriorates.

The DEEC/IDEEC will be referred to generically as the DEEC unless specifically referring to either the 220 or 229 engine.

BELOW: ***F-15E Strike Eagles assigned to the 366th Fighter Wing 'Gunfighters' taxi at Mountain Home Air Force Base, Idaho.*** *US Air Force/SSgt Jeremy Mosier*

*RIGHT: **F-15E 00-3001/LN assigned to the 494th Fighter Squadron based at RAF Lakenheath, England at seen low-level through a valley in Wales.** Dan Stijovich*

Engine Starting System

A self-contained jet fuel starter (JFS) is used to crank the engines for starting. The JFS is a small jet engine mounted on the central gearbox and along with the Airframe Mounted Accessory Drive (AMAD), provides rotation and initial electrical power for start. The JFS itself is started by accumulated hydraulic pressure. External power is not required during engine start. The JFS provides the only means of engine rotation for start.

Engine Air Induction System

The two independent air induction systems consist of three variable ramps, a variable diffuser ramp, and a variable bypass door.

The variable ramps provide air, at optimum subsonic flow, to the face of the engine fan inlet throughout a wide range of aircraft speeds. Ramp position is controlled by the air inlet controller.

The bypass door automatically relieves excess pressure in the inlet duct. The air inlet controller positions the bypass door.

An air inlet controller (AIC), one for each inlet, uses angle of attack, aircraft Mach number and other air data system outputs to automatically schedule the ramps and bypass door throughout the aircraft envelope. The first ramp is locked in the up position until the engine is started.

Engine Control System

The engine control consists primarily of a hydromechanical main fuel control (MFC), afterburner fuel control (AFC) and a full authority DEEC.

The engine control uses a digital primary control (PRI) with a backup hydrometrical secondary control (SEC).

During SEC mode operation, afterburner is inhibited, and engine thrust is limited to 70-80% MIL power in primary mode. The pilot can attempt to restore primary mode operation by cycling the ENG CONTR switch; if the fault that caused the transfer has cleared, the engine will return to primary mode.

Digital Electronic Engine Control - 220 Engines

The DEEC contains the engine operating schedules for automatic control from IDLE to MAX afterburner and is powered by the engine alternator. The DEEC schedules engine and afterburner fuel flows, compressor inlet variable vanes (CIVV), rear compressor variable vanes (RCVV), start bleed position, anti-ice, and nozzle position. The RCVV, start bleeds and engine fuel flow are scheduled by the MFC.

The DEEC controls engine performance by scheduling engine fuel flow to control airflow and nozzle position to control engine pressure ratio (EPR). EPR is the ratio between engine exhaust pressure and engine inlet pressure. By controlling airflow and EPR the engine performance is maintained consistent for a new or deteriorated engine until the fan turbine inlet temperature (FTIT) limit is reached. If the DEEC detects a failure that prevents it from safely controlling the engine it will automatically switch to the secondary mode, the same as ENG CONTR switch OFF. In this mode afterburner operation is inhibited, thrust is limited, the CIVV are in the fully closed position, the nozzle is closed to the minimum area (less than 5%) and the left or right ENG CONTR caution is displayed.

Improved Digital Electronic Engine Control - 229 Engines

The IDEEC contains the engine operating schedules for the same automatic control from start through MAX afterburner as provided by the 220 engine. The 229 IDEEC includes a ground idle thrust (GIT) setting to maintain equivalent 220 engine taxi performance. GIT is automatically activated with the aircraft on the ground and throttles near idle. Acceleration from ground IDLE to MIL power will be approximately one second longer than from approach or flight idle.

The 229 IDEEC also includes transient idle control logic. After a snap decel, engine speed will initially decrease to approximately 79% rpm , while thrust decreases to the requested throttle setting. If the throttle is not advanced for 20 seconds, engine speed will further decrease and stabilise at a steady state idle rpm with no additional thrust decrease. This control feature extends engine life and improves (MAX-IDLE-MAX and MIL-IDLE-MIL) response times.

Afterburner System 220 Engines

The afterburner has five stages that are progressively selected as the throttle is moved from MIL to MAX power. In the upper left corner of the engine envelope stages two through five may be inhibited.

Afterburner System 229 Engines

The afterburner has 11 segments that are progressively selected as the throttle is advanced from MIL to MAX power. The number of selectable afterburner segments is automatically reduced as the aircraft moves towards the upper left corner of the afterburner operating envelope. During snap accelerations, the first segment of the afterburner may, depending on flight condition, light at just above IDLE rpm and the succeeding segments will light as speed approaches MIL rpm. When MAX afterburner is selected, FTIT will increase by as much as 50°C over MIL power FTIT.

Light-Off Detector 220 and 229 Engines

The engine (220 or 229) uses a light-off detector (LOD) to signal the DEEC if a light-off occurs. The DEEC then schedules the AFC fuel flow for the remaining segments. If the LOD does not sense a light-off or a blowout occurs, the DEEC automatically resets the MFC to MIL power, terminates afterburner fuel flow and a check of the LOD is performed. If the LOD checks good, the DEEC will automatically attempt up to three more relights. If the afterburner still fails to light, retarding the throttle to MIL power or below will reset the DEEC and the system will operate normally when afterburner is reselected. If the LOD checks failed, the DEEC will attempt one relight, bypassing the LOD, using tailpipe pressure to verify an afterburner light-off. Afterburner light-off may take longer and appear to hesitate if the LOD is failed.

Afterburner is inhibited in the ENG CONTR OFF mode.

BELOW: ***An F-15E Strike Eagle receives fuel from a KC-135 Stratotanker assigned to the 340th Expeditionary Air Refueling Squadron over Iraq in support of Operation Inherent Resolve.*** *US Air Force/TSgt Larry Reid Jr*

RIGHT: ***F-15E 90-0243/ MO assigned to the 391st Expeditionary Fighter Squadron departs after receiving fuel from a KC-135 Stratotanker aircraft over the US Central Command area of responsibility on March 17, 2021.*** *US Air Force/SSgt Taylor Harrison*

Variable Area Exhaust Nozzle

The engine has a convergent-divergent nozzle system which is continuously variable between minimum and maximum opening. The nozzle is positioned pneumatically by engine bleed air.

Exhaust Nozzle Control 220 Engines

The nozzle is controlled by throttle position and landing gear handle position. With the gear handle down, throttle in IDLE and the DEEC on, the nozzle will be approximately 80% open. As the throttle is advanced, the nozzle closes to near minimum area.

With the landing gear handle up, the nozzle is near minimum area at all times except at MIL power or above. At MIL power the nozzle indicators will show the nozzles slightly open (5-10%). As the throttle is advanced in the afterburner range the nozzles will schedule further open to compensate for increasing afterburner fuel flow. With the DEEC off or in secondary mode, nozzle position will be closed to near the minimum area in flight or on the ground, this will result in higher idle thrust and taxi speeds.

Exhaust Nozzle Control 229 Engines

The exhaust nozzle is controlled by the throttle position and landing gear handle position. With the gear handle down, throttle in IDLE and the IDEEC on, the nozzle will be approximately 80-100% open.

As the throttle is advanced, the nozzles close to near minimum area. With the landing gear handle up, the nozzle is near minimum area (10%) when the throttle is below MIL power. At subsonic speeds with the throttles at MIL power, the nozzles will generally be less than 20% open; at supersonic speeds with the throttles at MIL power, the nozzles can be as high as 45% open. As the throttle is advanced in the afterburner range, the nozzle will schedule further open to compensate for increasing afterburner fuel flow. With the IDEEC off, nozzle position will be closed to near minimum area (55%) inflight or on the ground. This results in higher idle thrust and taxi speeds.

SYSTEMS

Airframe Mounted Accessory Drive (AMAD)

The left and right AMAD gearboxes are directly connected to their respective engine, utility hydraulic pump, power control (PC) hydraulic pump, and integrated drive generator (IDG). During engine start, power is transmitted from the JFS through the CGB and through the applicable AMAD gearbox to the engine. Once the engine is started, the CGB decouples from the AMAD gearbox and the engine then drives the AMAD gearbox and its associated accessories.

The accessories on either AMAD gearbox are sufficient to support the aircraft systems if one engine or its associated AMAD gearbox fails.

Aircraft Fuel System

Fuel is carried internally in four interconnected fuselage tanks, and two internal (wet) wing tanks. External fuel can be carried in three external tanks and two conformal fuel tanks (CFTs). The external tanks are mounted on the centreline and inboard wing station pylons and are completely interchangeable.

CFT's are mounted on the outboard side of each engine nacelle. All tanks may be refuelled on the ground through a single pressure refuelling point, airborne they can be refuelled through the aerial refuelling receptacle. External tanks may be individually fuelled through external filler points. The internal wing tanks and tank 1 are transfer tanks. Tank 1 consists of one main tank and a right auxiliary tank.

The tanks are so arranged that all internal fuel will transfer even if the transfer pumps fail. CFT fuel is transferred by transfer pumps to any internal tank that will accept it. Regulated engine bleed air pressure transfers fuel from the external tanks to any internal tank that will accept it and also provides a positive pressure on all internal fuel tanks. Each CFT is pressurised by a self-contained ram air pressurisation and vent system. Float type fuel level control valves control fuel level during refuelling or fuel transfer operations. All internal, CFT and external fuel (except engine feed tanks) may be dumped overboard from an outlet at the trailing edge of the right wing tip. All internal fuel tanks are vented through the vent outlets at each wing trailing edge. The external tanks are vented through the vent outlets in their individual pylons. Each CFT is vented through an outlet near the back of the CFT. The fuel quantity indicating system provides fuel quantity, in pounds, of all internal, CFT and external fuel.

Survivability

The internal fuel tanks, all of which are located forward of the engines, contain foam for fire explosion protection. The feed tanks are self-sealing. Fuel lines are routed inside tanks where possible, and most have self-sealing protection when outside the tanks. All CFT compartments incorporate explosion suppression foam slabs for enhanced survivability.

Dry bay areas (voids) around fuel cells on the sides and bottom of fuselage fuel tanks are filled with explosion suppression polyether foam.

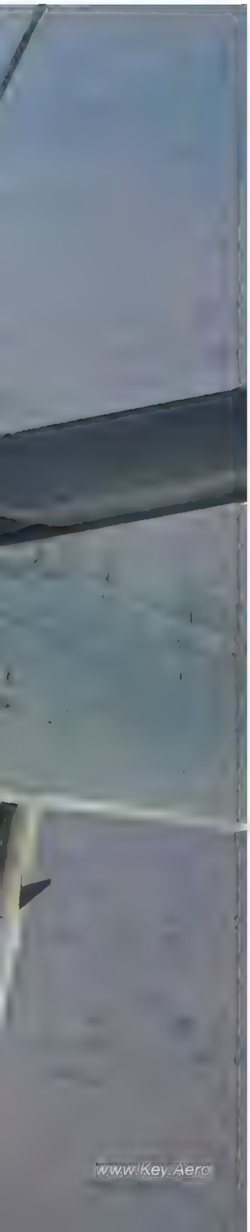
Fuel Transfer System

The fuel transfer system provides for internal and external fuel transfer. Internal fuel consists of left and right internal wing tanks, left and right engine feed tanks, right aux tank, and tank 1. External fuel consists of left and right CFT, left and right external wing tanks, and the external centreline tank.

Internal Fuel Transfer

Internal fuel transfer is accomplished by three electric transfer pumps (left and right internal wing tanks and tank 1) and one fuel ejector pump (right aux tank). The electric pumps automatically transfer internal wing and tank 1 fuel to the engine feed tanks when the level control valve(s) in either of the two feed tanks is open. The transfer pumps run continuously when electrical power is applied to the aircraft and an engine master switch is on. However, tank 1 transfer pump will not run unless the slipway switch is in CLOSE even if the FUEL LOW light is on. During normal operation 200 pounds of tank 1 fuel will transfer before the internal wing tanks start transferring.

This sequence causes the centre



of gravity (CG) to move aft. Once the internal wings start feeding, they will simultaneously transfer along with tank 1 to the engine feed tanks. This is true during all engine operations both on the ground or in flight. Although tank 1 fuel quantity is initially higher (approximately 550 ± 200 pounds) than either internal wing tank, the transfer rate of tank 1 and the internal wing tanks is designed so that tank 1 and the wing tanks empty within 200 pounds of each other. If the electrical transfer pumps fail, fuel from all internal tanks will gravity transfer at a reduced rate to the engine feed tanks. Check valves prevent fuel flow from the feed tanks to the transfer tanks. The fuel ejector pump in the right auxiliary tank automatically transfers fuel to main tank 1 when its transfer pump is operating or the ejector pump or tank 1 transfer pump fails, fuel will gravity transfer (through the open ejector pump) at a reduced rate as the level of main tank 1 decreases.

External Wing and Centreline Tank Transfer

External wing and centreline fuel is transferred by engine bleed air pressure providing the landing gear handle is up. External fuel will not transfer with the landing gear handle down or with the slipway switch in OPEN unless the FUEL LOW light comes on. If a complete electrical failure occurs, the external fuel will still transfer. There is no backup provision for the external fuel transfer system. External fuel will normally transfer before the internal tanks start to deplete. External wing tank fuel may not transfer at the same rate or even together but will normally transfer before centreline fuel. Internal and all external tanks can deplete simultaneously whenever engine fuel consumption exceeds transfer capability.

Conformal Fuel Tank Transfer

Each CFT contains two transfer pumps, one in the centre compartment sump and one in the aft compartment sump. The sumps are connected by a float controlled interconnect valve which isolates the sumps until the aft compartment is almost empty or the aft transfer pump fails. Each CFT also contains an ejector pump that transfers fuel from the forward compartment to the centre compartment. The centre pump transfers forward/centre compartment fuel and the aft pump transfers aft compartment fuel. When the aft compartment fuel level drops below an interconnect float valve level, the interconnect valve opens connecting the two sumps. The CFT transfer pumps run continuously when electrical power is applied to the aircraft, an engine master switch is on, the slipway switch

ABOVE: *F-15E 87-0174/SJ assigned to the 335th Fighter Squadron 'Chiefs' launches from Nellis Air Force Base, Nevada. The aircraft is loaded with an ASQ-236 radar pod with synthetic aperture radar mode that generates detailed maps for surveillance, coordinate generation and bomb impact assessment purposes.* Dan Stijovich

is in CLOSE, CFT is selected on the external transfer switch, and NORMAL is selected on CFT STOP TRANSFER/REFUEL switch. Fuel transfer sequence within the CFT is designed so the CG moves forward as the CFT transfers fuel. Improper fuel sequencing from the CFT may cause the CG to remain or move aft while the CFT transfers fuel.

Fuel Dump System

All fuel except engine feed tank fuel may be dumped by placing the dump switch, on the fuel control panel, to DUMP. With the landing gear handle DOWN, external fuel cannot be dumped since it cannot be transferred to the internal tanks. The fuel dump switch is spring-loaded to the lever-locked NORM position and is electrically held in the DUMP position (with BINGO caution off). When DUMP is selected, a motor-operated dump valve in the right internal wing tank opens. With the dump valve open, the transfer pumps in tank 1 and each internal wing tank force fuel out the right wing dump mast. Conformal fuel tanks and/or external fuel tanks transfer into tank 1 and the wing tanks and is then dumped. Dumping will continue until STOP TRANS is selected or in the case of the external tanks, the landing gear handle is moved to DOWN. If the tank 1 and internal transfer pumps fail, external fuel passes through a check valve and is dumped.

The approximate fuel dumping rates are right internal wing tank 390 pounds per minute (PPM), left internal wing tank 260 PPM, and tank 1, 260 PPM for a total of 910 PPM.

The uneven dump rates of the internal wing tanks produce a fuel imbalance (left wing heavy) of approximately 130 pounds per minute up to a maximum of approximately 1,100 pounds of wing fuel asymmetry. Wing fuel asymmetry will remain until all the fuel in the internal wing tanks is depleted.

The external fuel tanks may be jettisoned individually or simultaneously.

Air Refuelling System

The air refuelling system has a fixed receptacle, a slipway control switch, a hydraulically operated slipway door, two slipway lights, a receptacle floodlight, a signal amplifier, a READY light, an air refuelling release button, an air refuel pressure switch, and an emergency slipway door actuating system. For CG control, a float switch in tank 1 prevents external tank refuelling until tank 1 fuel quantity is above approximately 1,560 pounds. The CFTs start filling immediately (regardless of tank 1 fuel quantity) with CG being maintained by the sequence in which the CFT compartments are filled.

Hydraulic Power Supply System

Hydraulic power is supplied by three separate systems with each system divided into two or more circuits. Reservoir level sensing (RLS) is employed in all three systems for the purpose of isolating a leak. When a leak develops in a circuit a valve senses the reservoir level and shuts off the affected circuit. Through this method the maximum number of circuits remain operable.

Power Control Systems

Both power control hydraulic system pumps, PC1 and PC2, operate at a pressure of 3,000psi. Each power control system is divided into a circuit A and a circuit B.

Landing Gear System

The gear is electrically controlled and hydraulically operated. While weight is on the gear, the gear cannot be retracted. When the main and nose gear are extended, the forward door(s) will be closed.

Nose Gear Steering System

Nose gear steering (NGS) is a full time mechanically controlled (front and rear cockpit rudder pedals) hydraulically powered system that features dual authority steering ranges consisting of a normal (15° maximum left or right) range and a manoeuvring (45° left or right) range. The steering system automatically engages whenever the nose gear strut is

compressed by the weight of the aircraft and provides normal steering authority range. The manoeuvring range is selected by pressing the NGS button on the front cockpit control stick. The nose gear steering system may be disengaged from either cockpit by pressing and holding the paddle switch on the control stick. With the system disengaged, the nose wheel becomes free swivelling and may be swivelled 360°. When the paddle switch is released, the system will not re-engage if the nose gear has rotated more than approximately 56°.

However, if the steering is engaged with the nose gear rotated beyond 45°, the nose gear will be immediately driven back to the 45° position. During taxi, when centring action reduces the angle below approximately 45°, the nose gear steering system will re-engage. On take-off, nose gear steering is disengaged when the nose gear strut extends.

Brake System

The main landing gear wheels are equipped with hydraulically powered brakes operated by toe action on the rudder pedals. An anti-skid system is incorporated in the normal brake system to provide maximum deceleration with controlled wheel skid. An emergency brake system provides JFS hydraulic accumulator pressure to power the brake system in the event of loss of UTL A which normally powers the system. Anti-skid protection is not available on the emergency brake system. A holding brake relieves the aircrew from maintaining pressure on the brake pedals when the aircraft is stopped for long periods of time.

Anti-Skid System

The anti-skid system is electronically controlled by a three-position switch in the front cockpit on the miscellaneous control panel. An ANTI-SKID caution and the MASTER CAUTION light will come on whenever the landing gear is down, and a system failure is detected. A touchdown protection circuit (with anti-skid on) prevents hydraulic pressure from being applied to the brakes until both main wheels spin up. The brake pulser provides main tyre skid control in the event that anti-skid braking is not available. Skid control effectiveness deteriorates below 30kts; therefore, heavy braking below 30kts may result in locked wheels.

Flap System

Each wing has a two-position trailing edge flap. The flaps are electrically controlled and hydraulically operated. When the flaps are down, they are protected from structural damage by a blow up airspeed switch. The switch is set to automatically retract the flaps at 250kts maximum. The flaps will automatically return to the down position at no less than 230kts, providing the flap control switch is in the down position.

Speed Brake System

A speed brake is located on the upper surface of the centre fuselage just aft of the canopy. It is electrically controlled and hydraulically operated. The speed brake can be positioned to any intermediate position between fully retracted and fully extended with angle-of-attack (AOA) below approximately 25 units. If AOA is above 25 units, the speed brake will not extend when selected. If the speed brake is extended, it will automatically retract when AOA increases through 25 units.

If the central computer detects a failure in the AOA system, the ground to the speed brake switch is broken and the speed brake, if extended, will retract. If the AOA failure occurs with the speed brake closed, it cannot be extended. Following automatic retraction of the speed brake, when AOA is reduced, the speed brake will automatically extend provided the speed brake switch is in the out position.

Flight Control System

The aircraft primary flight control surfaces consist of conventional ailerons, twin rudders and stabilators (which are capable of symmetrical or differential movement). Hydraulic actuators are used to position the control surfaces. The inputs to the hydraulic actuators are from a hydromechanical system and an electrical system called the control augmentation system (CAS). The hydromechanical system and the CAS normally work together, but either system alone is capable of providing sufficient aircraft control for flight. Spring cartridges provide simulated

BELOW: ***F-15E Strike Eagles from the 336th Fighter Squadron 'Rocketeers' based at Seymour Johnson Air Force Base fly in formation over North Carolina.*** *US Air Force/ Airman 1st Class Kimberly Barrera*

LEFT: ***Seen at its home station Luke Air Force Base, Arizona in March 1990, F-15E 87-0179/LA assigned to the 461st Tactical Fighter Training Squadron, a component of the 405th Tactical Training Wing, the then F-15E Replacement Training Unit.*** *Dan Stijovich*

aerodynamic forces to the control stick and rudder pedals. The spring cartridges have trim actuators which actually move the neutral positions and thus the control surfaces.

Control Stick

The front cockpit control stick consists of a stick grip and force transducer and contains seven controls: an autopilot/nose gear steering disengage switch (paddle switch), nose gear steering/weapons button, a trigger, a weapon release button, a trim switch, an auto acquisition button, and a castle switch. The rear cockpit control stick consists of a stick grip and force transducer and contains four controls: an autopilot/nose gear steering disengage switch (paddle switch), a weapon release button, a trim switch, and an air refuelling release button. The rear cockpit trigger is non-functional.

Rudder Pedals

The rudder pedals operate conventionally and are adjustable. The rudder pedals are also used for the brakes and nose gear steering.

Automatic Flight Control System (AFCS)

The AFCS provides roll, pitch, and yaw control augmentation, autopilot modes in roll and pitch axis, and terrain following in the pitch axis.

Control Augmentation System (CAS)

Superimposed on the hydromechanical flight control system is a three-channel, three-axis control augmentation system. The CAS responds to electrical signals generated by forces applied to the control stick and to rudder pedal position. These signals modify the control surface deflections commanded by the hydromechanical flight control system to provide the desired flying qualities. The CAS also provides increased damping on all three axis. Since CAS inputs are applied directly to the actuator and the inputs are due to force and require no control stick or rudder motion, with the CAS on, limited aircraft control is retained with the loss of any or all mechanical linkages. The three-channel design turns any axis off when a second like failure occurs. The CAS affects stabilator and rudder position only; the ailerons are not controlled by the CAS.

Central Computer

The central computer (CC) is a high speed, stored program, general purpose digital computer that performs mission oriented computation from data received from control panels and subsystems aboard the aircraft.

The computations include air-to-air and air-to-ground steering and weapon delivery, navigation, flight director, and control and display management.

The CC computations are controlled by the operational flight program stored in the CC memory. Failure detection of the peripheral systems and CC internal operation is done by continual monitoring. Back-up system substitution is also accomplished in the central computer. If the computer detects a power loss or failure, there is a drastic change in the display formats. In the front cockpit, the left MPD displays the radar air-to-air format (with air-to-ground format selectable), the MPCD displays attitude direction indicator (ADI), the right MPD displays tactical electronic warfare system (TEWS), and the HUD shows a backup format. In the rear cockpit, the left MPCD displays ADI, the left MPD has a radar display, the right MPD displays TEWS data, and the right MPCD displays TSD (tactical situation display) data.

Central Computer Interface

The central computer is interfaced with the radar, programmable armament control system, automatic flight control system, air data computer, attitude heading reference system, multipurpose display system, head-up display, signal data recorder, radar warning receiver, inertial navigation unit, the engine diagnostic unit, and the avionics status panel.

Multiplex Bus

Coded messages are transmitted between the CC and remote terminals in both directions on the multiplex bus. The coded messages are in serial digital format. The CC (or multipurpose display processor in backup mode) establishes communications on the avionics 1553 bus by scheduling all messages. Messages are blocks of data that contain the total information to be transferred. The blocks of data in a message are called words. There are three types of words: command, status, and data. The CC (or multipurpose display processor in backup mode) gives commands, inspects status and receives/sends data.

Data Transfer Module Set (DTMS)

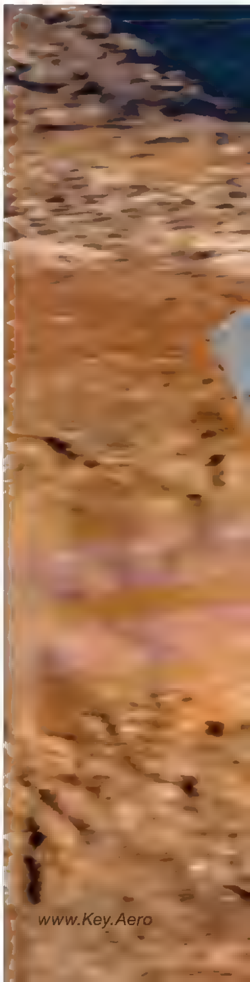
The DTMS consists of the main instrument panel Data Transfer Module Receptacle (DTMR) and the Data Transfer Module (DTM). Mission data is loaded, by the aircrew or operations personnel, on the ground and stored in the module. The module is carried to the aircraft, inserted into the DTM receptacle to initialise mission data.

The DTM READ function transfers mission data for sequence points, tacan stations, list points, HUD titler, crew station display programming, radar display programming, communications, IFF modes and codes, programmable armament control system (PACS) air-to-ground programs (combat or training modes), weapon delivery and PACS weapon loaded data (combat or training modes).

The DTM WRITE function receives mission data from the CC by way of the MPDP for HUD titler, air-to-air or air-to-ground engagement, caution advisories, engine monitor, avionics BIT monitor (radar and other avionics, continuous and initiated), terrain following data and AFCS data.

Hand Controllers

The left and right hand controllers located on the forward inboard section



of the left and right rear cockpit consoles, are used to provide sensor/display control.

Upfront Controls (UFC)

The upfront controls in the front and rear cockpit are the major interface units for control of avionics subsystems.

The UFC consists of 10 function buttons, six 20-character rows of display, four radio volume controls, two rotary switches, a 20-key data entry keyboard, and a rotary brightness control knob.

UFC Displays

Since a large number of system functions have been integrated into the UFC several menus or display formats were developed. These displays are called data displays, menus, and submenus. There are two data displays, two menus and 19 submenus. Regardless of the data or submenu displayed, the radio communication information is always retained.

Tactical Situation Display (TSD)

The TSD is a presentation of aircraft position with respect to a planned mission route superimposed over a moving map format. Its primary function is to provide planned navigation information and sensor positioning control to the crew. The best display for its presentation will be on the MPCD so that the advantages of having the moving map in colour are realised. Two primary operational uses of this display are navigation (position awareness) and sensor cueing operation.

Canopy System

The cockpit area is enclosed by a clamshell type canopy and an impact resistant windshield. The main components of the canopy system are a hydraulic actuator which provides manual and powered operation of the canopy, a locking mechanism, and a pyrotechnic canopy remover for emergency jettison. Latches on the canopy frame and along the lower edge of the canopy engage fittings on the cockpit sill structure to lock the canopy to the fuselage. An inflatable seal, installed around the edge of the canopy frame, retains cockpit pressure when the canopy is locked.

Ejection Seat System

An ejection seat is installed in each cockpit and a sequencing system is provided which allows for selection of various single or dual ejection options. Once ejection is initiated, whether dual or single, each ejection seat is a fully automatic catapult rocket system. Three ejection modes are automatically selected. Mode 1 is a low speed mode during which the parachute is deployed almost immediately after the seat departs the aircraft; Mode 2 is a high speed mode during which a drogue chute is first deployed to slow the seat, followed by the deployment of the parachute; Mode 3 is a high altitude mode in which the sequence of events is the same as mode 2 except that man-seat separation and deployment of the parachute are delayed until a safe altitude is reached. Controls are provided to adjust seat height and lock shoulder harness.

The ejection seat is equipped with primary and redundant ejection systems and a canopy breaker. The primary and redundant systems are isolated and independent of each other. Both ejection systems are initiated simultaneously when an ejection control handle is pulled. However, a built-in delay in the redundant system allows the primary system to work before the redundant system starts. The time delay prevents any interference of primary and redundant system ejection sequencing. Also, if the primary system fails prior to canopy jettison, the redundant system will jettison the canopy and eject the seat. If both the primary and redundant system fail to jettison the canopy, the redundant system will still fire the seat catapults and with the addition of the seat mounted canopy breaker, provide through the canopy ejection. The redundant system will eject the seat regardless of canopy position (open, closed, or in-between).

BELOW: ***F-15E 87-0180/ET with tail markings for the 96th Operations Group commander. The aircraft, based at Eglin Air Force Base, Florida, is assigned to the 40th Flight Test Squadron tasked with development testing of all new software and hardware destined for the F-15E. The panels painted bright orange denote a component under test.***
Dan Stijovich

GENERAL HANDLING QUALITIES AND CONFIGURATION IMPACTS ON HANDLING QUALITIES

The original design of the flight control system was to provide uniform handling qualities throughout the entire flight envelope. However, due to the growth of the F-15E, the flight control system is no longer capable of providing uniform handling qualities. As a result , handling qualities vary with aircraft load, weight, centre-of-gravity (CG), and automatic flight control system (AFCS) failures. Initially this section discusses the handling qualities of an aircraft with no CFTs, LANTIRN pods or external stores at nominal weight and CG conditions. Then it shifts focus to discuss the effect of configuration and weight changes on those handling qualities.

Flight with Centre of Gravity at Limits

The distribution of fuel among the fuselage tanks, CFT compartments, and external tanks will affect the aircraft CG position. For specific external stores configurations, fuel distribution may result in CG excursions beyond the accepted limits.

Static CG travel for the F-15E configured with F100-PW-220 engines and loaded with typical air-to-air and air-to-ground stores will be different to an aircraft configured with F100-PW-229 engines due to the weight difference of the engines and ballast requirements. The F100-PW-229 engines increase the aircraft weight by 1,200lb and shift the CG aft approximately 0.8%.

The difference in the CG travel is the result of degraded performance of the CFT aft compartment transfer system. There are three contributors to this degraded transfer performance: (1) forward/centre compartment transfer into the aft compartment through the sump vent hole; (2) unavailability of aft compartment fuel at high AOA/fuel angles due to forward location of the aft compartment pump; (3) transfer of forward fuel into the centre compartment by gravity transfer and ejector pump. The effect of this fuel transfer situation may occur at any indicated CFT quantity. The situation described above is aggravated by aggressive aircraft manoeuvring particularly at high AOA combined with both normal and level acceleration. The resulting fuel angle will contribute to the problem by temporarily trapping fuel in the aft compartment of the CFT, which will then transfer out when the aircraft levels off. Since the fuel gauge shows only the total CFT fuel quantity, monitoring is impossible.

Flight at Heavy Gross Weights

Although there is less pitch damping at heavy gross weights, the handling qualities of the aircraft are not significantly degraded. Due to the control augmentation system, a heavy gross weight aircraft will be as responsive as a light weight aircraft. With this responsiveness, the pilot can put the aircraft in a high AOA high sink rate condition with little warning.

This weight masking effect is of particular concern during traffic patterns and landing. For this reason, a wide pattern or straight-in approach is recommended. Fly final approach at on-speed AOA, but delay reducing power until well into the flare to prevent an excessive sink rate. Expect the nose to drop at significantly higher airspeeds during aerobraking.

Although the control system will often mask weight effects, the aircraft response to control inputs may be initially slowed by high inertias with partially-full to full CFTs. Longitudinally, the higher inertias will always be partially offset by the increased pitch response caused by the aerodynamic effects of the CFTs. Aircraft flying qualities during aerial refuelling and formation flying are good, although higher power settings will be required for these manoeuvres than with an aircraft without CFT's. The closed loop stability of the terrain following system is such that aircraft ride quality may be degraded when terrain following at heavy gross weights.

Flight with Asymmetric Loads

During take-off roll, an aircraft with a heavy wing will tend to turn toward the heavy side. Some opposite rudder will be required to counter the inertia of the heavy wing. On rotation, the aircraft will tend to roll into the heavy wing requiring some opposite lateral stick. Abrupt pitch changes as the aircraft is rotated for take-off should be avoided.

Required control inputs with asymmetric loads change significantly with AOA. At low AOAs and high speeds, some lateral stick away from the heavy wing is required. Some rudder away from the heavy side may also be required. However, as AOA is increased to beyond 30 units, the aircraft will tend to yaw and roll away from the heavy wing. The resulting sideslip angle will require lateral stick towards the heavy wing to stop the roll. Rudder pedal towards the heavy wing may also be needed to stop the yaw rate. The tendency for the aircraft to yaw away from the heavy wing will eventually overpower the control surfaces at high AOA. Motions in yaw are difficult to detect and may be more readily identified by an un-commanded rolling motion. The end result will be that the aircraft will depart in yaw and roll and eventually spin away from the heavy side if AOA is not reduced.

Yawing moment due to asymmetric

BELOW: ***Assigned to the 40th Flight Test Squadron, F-15E 87-0180/ET loaded with inert Mk82 and Mk84 general purpose bombs.*** *Dan Stijovich*

ABOVE: ***When F-15E 90-0241 was delivered to the US Air Force it was assigned to the 90th Fighter Squadron, a component of the 3rd Wing based at Elmendorf Air Force Base, Alaska. The jet is seen at Nellis in April 2000.*** *Dan Stijovich*

drag also has some effect but is usually much smaller than the effects due to weight asymmetry. The presence of a centreline tank, because of its destabilising effect on lateral-directional stability, will further aggravate the departure tendencies at high AOA. High AOAs, high subsonic Mach, and higher altitudes tend to amplify the characteristics created by the asymmetry.

Lateral asymmetries as great as one full external wing tank may be safely flown to 30 units AOA. Above 30 units, little capability remains to control yaw and roll due to the asymmetry. If the critical AOA for any given asymmetric loading is exceeded, the aircraft will yaw and roll in the direction opposite the heavy wing. At higher AOA, this motion can be quite rapid.

In addition to increased departure susceptibility, lateral asymmetry also degrades recovery characteristics.

As the asymmetry increases, the recovery is delayed. Control can be regained by reducing AOA and increasing speed.

Landing may be made with asymmetric loading if turns are shallow, and a flat approach is flown. Fly final approach at on-speed AOA, but delay reducing power until well into the flare. A large or abrupt flare should be avoided. With a large asymmetric load, crosswinds from the light wing side in excess of 15kts should be avoided. If in doubt, the pilot should perform a controllability check before landing.

Lateral asymmetries have a pronounced effect on roll performance during negative g flight. Loss of roll control authority during negative g flight is possible with large lateral asymmetries (greater than 10,000ft-lbs). This can occur during negative g flight with as little as -0.8g.

Low Altitude High-Speed Flight

The aircraft is susceptible to wind gusts during low altitude high-speed flight due to low wing loading/high wing lift characteristics. In areas of very heavy turbulence, such as found in mountainous desert terrain, flight above about Mach 0.8 may induce abrupt vertical motions. Minor lateral/directional motion will occur. None of these disturbances significantly alter the flight path. Flight with external stores increases the wing loading and reduces the effects of gusts.

Slow Speed Flight

The aircraft exhibits no unusual slow speed flight characteristics. With symmetrical loads, the handling qualities remain acceptable until there is insufficient airflow over the wings and control surfaces to provide adequate lift or control. In many cases, at very slow speed, full aft stick and/or a pegged vertical velocity indicator may be the only sign(s) of a low energy 1 g stalled condition.

With asymmetrical loads, the pilot should maintain a minimum of 300KCAS except during low-speed tactical manoeuvres, maximum range descents, holding, or instrument approaches and landings. This minimum airspeed provides reasonable handling qualities and adequate manoeuvring margins for terrain and collision avoidance.

MAIDEN FLIGHT AND PRODUCTION

The F-15E made its maiden flight from Lambert Field, St Louis, Missouri on December 11, 1986. McDonnell built 236 F-15E aircraft between 1985 and 2001, which were all delivered to the US Air Force. Variants of the F-15E are operated by Israel (F-15I), the Republic of South Korea (F-15K), Saudi Arabia (F-15S and F-15SA), and the Republic of Singapore (F-15SG). Each variant is covered in separate sections of this publication.

F-15E Characteristics

Length	63ft 9in
Wingspan	42ft 9.75in
Height	18ft 5.5in
Tailplane span	28ft 3in
Vertical stabiliser spacing	11ft 3in
Wheel track	8ft 11in
Wheelbase	17ft 9in
Wing area	608ft^2
Empty weight	31,700lb
Max take-off weight	81,000lb
Ceiling	60,000ft
Max speed	Mach 2.5 plus at 45,000ft
Combat radius	680nm unrefuelled
Ferry range with conformal fuel tanks and three external fuel tanks	2,100nm

Israel's KILLER FIGHTER

Riccardo Niccoli describes Israel's all-conquering F-15 Baz. Additional details by **Mark Ayton.**

The requirement to introduce a new generation air superiority fighter into Israeli Air Force service had already been realised before the Yom Kippur war in 1973. The need was made more urgent by the appearance of four Soviet Air Force MiG-25 Foxbat aircraft at Egypt's Cairo West Airport in March 1971The quartet comprised two reconnaissance-configured MiG-25Rs and two MiG-25RBs which had an air-to-ground capability. The Mach 2.5-capable MiG-25Rs commenced operational reconnaissance missions over Israel, futilely pursued by Israeli Air Force F-4E Phantoms and ineffectively targeted by Israeli MIM-23 surface-to-air missiles. Between early October 1971 and April 1972, the Soviet MiG-25 pilots flew a series of missions on tracks that followed the coastline of Israel and the Sinai Peninsula, and eventually over the Sinai.

Tomcat vs Eagle

Abandoned to the idea of the F-4X programme once it was dropped by the US Department of Defense, in August 1972, an Israeli delegation visited the United States to gather information on America's two new fighters: the Grumman F-14 Tomcat and the McDonnell F-15 Eagle.

BELOW: ***F-15D Baz 715 assigned to the Knights of the Twin Tail Squadron on take-off from Nellis Air Force Base, Nevada during an exercise in September 2002.*** *Dan Stijovich*

RIGHT: ***F-15D Baz 450 takes off at Uvda Air Base, Israel during Blue Flag 2013, Israel's annual multinational air warfare exercise.*** *US Air Force/MSgt Lee Osberry*

In June 1974, in the aftermath of the Yom Kippur War, the Israeli Ministry of Defence issued a requirement for the acquisition of 50 new generation fighters, together with a request to evaluate both the F-14 and the F-15. In September, a team comprising test pilots and engineers from the Israeli Air Force and Israeli Aircraft Industries arrived in the United States. At that time, the F-15 Eagle had not entered service with the US Air Force, so the Israeli team undertook an in-depth evaluation of the jet which included flying 1 v 1 Dissimilar Air Combat Training missions between a two-seat TF-15 and a F-4. Similar missions were flown between a F-14 and a A-4.

Israeli test pilots sought to determine the close combat capability of each aircraft in scenarios that replicated the Israeli theatre in which there was little opportunity for long range interceptions.

The results surprised the Israelis, especially because the F-14 did not have an edge over the A-4 in close combat. The final report left nothing to doubt: The Eagle was more flexible, more manoeuvrable, and had more power and energy than the Tomcat, and could be flown in a more aggressive way. Additionally, acquisition and support costs for the F-15 were cheaper. In short, the McDonnell Douglas F-15 was preferred to Grumman's F-14 Tomcat.

Offer and Acceptance

In December 1974, the Ford Administration offered Israel 48 F-15A Eagles. However, due to the high costs of the deal which was offered as a foreign military sale (FMS) programme and slow progress in the peace talks between Egypt and Israel, in September 1975 the US government decided to provide 25 aircraft at an overall cost of $625m.

To accelerate deliveries, some of the initial aircraft supplied to Israel were drawn from a batch of Full Scale

LEFT: ***F-15B Baz 111 is one of six former US Air Force aircraft supplied to Israel under the Peace Fox V programme in 1991-1992 with The Point of the Spear Squadron markings applied.*** *Riccardo Niccoli*

Development (FSD) aircraft, which were upgraded series production standard F-15A Eagles. The Israeli government and Ministry of Defence were unhappy with this aspect of the programme but agreed to a compromise: Four FSD (Category II) aircraft would be delivered in short time, followed by 21 series production standard aircraft. Under the FMS system, the Israeli programme was named Peace Fox.

Many Israelis considered the experiences from the Yom Kippur war required its government to purchase not only quality, but also quantity, and 25 aircraft appeared to be too few in the light of a new war. In addition, the F-15 was viewed as a pure fighter, while many Israelis considered that its government should purchase a multirole aircraft, such as the F-4.

Delivery of the first three Eagles (one of the four made an emergency landing in Italy), occurred late in the evening of Friday December 10, 1976 at Tel Nof Air Base. However, it provoked a political crisis, and forced Prime Minister Yitzhak Rabin to dissolve his government and call a new election after a motion of no confidence was brought by the ultra-orthodox Agudat Yisraef party. They cited the F-15 delivery ceremony had broken the religious rule of the Sabbath. Someone noted ironically that Rabin's Labour government was the first kill of the F-15.

The F-15s were assigned to the newly established Knights of the Twin Tail Squadron based at Tel Nof, commanded by Lieutenant Colonel Eitan Ben-Eliyahu, a highly-experienced former F-4E commander with three kills to his credit.

Ben-Eliyahu and four more experienced pilots were sent to Luke Air Force Base, Arizona between July, and November 1976, and assigned to the 555th Tactical Fighter Training Squadron, a component of the then 58th Tactical Fighter Training Wing. The five pilots completed the US Air Force's F-15 operational conversion course and became the first Israeli pilots qualified on the Eagle. On December 12, Lieutenant Colonel Eitan Ben-Eliyahu flew F-15, serial number 622, on the type's first flight in Israel.

The remaining 21 aircraft (ten Block 17 F-15A, nine Block 18 F-15A, and two Block 16 TF-15A aircraft, later re-designated F-15B) were delivered in late 1977 and early 1978. In Israeli Air Force tradition, the F-15 was given the Hebrew name Baz (Buzzard).

Operational Service

In March 1978, the Baz carried out the type's first operational combat air patrol (CAP) missions in support of the Israeli Army's invasion of Southern Lebanon under Operation Litani: an effort to destroy the Palestinian Liberation Organisation's infrastructure. Baz missions were flown armed with infrared-guided Rafael Python 3 air-to-air missiles.

Air combat soon followed. On June 27, 1979, the Israeli Air Force ambushed Syrian Air Force MiG-21s while the MiG pilots were attempting to intercept some Israeli fighter-bomber aircraft launched over Lebanon. According to official Israeli sources, thanks to Israeli electronic countermeasures, the MiGs were deprived of radio contact with their GCI controllers as four F-15s climbed from low level and launched AIM-7F Sparrow missiles, which missed the targets. A close combat engagement followed. During the initial engagement two MiG-21s were shot down with Python 3 and AIM-7F missiles. In the second engagement two more MiG-21s were downed; one with the M61 Vulcan cannon and one with an AIM-9G Sidewinder missile. These were the first air-to-air victories for the F-15 Eagle.

Seven more Syrian MiG-21s were downed by Israeli F-15s; four on September 24, 1979, one on August 24, 1980, and two on December 31, 1980.

On February 13, 1981, two Israeli reconnaissance-configured RF-4E Phantoms entered Lebanese air space at 40,000ft flying at over the speed of sound. Within minutes, two Syrian MiG-25Ps were scrambled forcing the RF-4E pilots to dispense chaff and turn south at which point the two MiGs were at 30,000ft and a range of 54nm. This was an Israeli ambush. An F-15A piloted by Lieutenant Colonel Benny Zinker was already airborne climbing from low-level toward the two MiGs which were already under attack by Israeli electronic countermeasures. From below at a range of 22nm, Zinker fired two AIM-7F missiles, one of which hit a Foxbat. This was the first kill on a MiG-25. A second Syrian MiG-25 was downed on July 29, 1981.

On June 7, 1981, F-15s undertook an escort role in the attack on the unfinished Iraqi nuclear reactor at Osirak conducted by brand new F-16A fighter-bombers. Six F-15s took-off from Etzion Air Base and other aircraft were held on alert to scramble in case of an enemy counter-attack. One F-15B was modified with an HF radio and an antenna glued to the canopy to serve as a command post during the mission.

The F-15's demonstrated prowess and combat advantage versus adversary aircraft and the availability of the improved F-15C model, quickly led the Israeli government to acquire a second 15-aircraft batch in 1978 under the Peace Fox II foreign military sales programme. The first aircraft were delivered on August 25, 1981 with all but three aircraft delivered in 1982 before the invasion of Lebanon under Operation Peace for the Galilee. That operation launched on June 6, 1982, the very day that The Point of the Spear Squadron was activated at Tel Nof Air Base to fly the new Baz 2 aircraft.

Due to the war, all the available F-15s were operated by the Knights of the Twin Tail Squadron, which was tasked to provide air superiority over the combat zone. In just six days, the Israeli Air Force shot down 92 Syrian Air Force aircraft of various types, 33 of which

BELOW: ***F-15C Baz 818 assigned to the Knights of the Twin Tail Squadron parked on the flight line at Tel Nof loaded with live AIM-7 Sparrow and Python 4 air-to-air missiles, and GBU-31 Joint Direct Attack Munitions.*** *Israeli Air Force*

were credited to the Knights of the Twin Tail Squadron and 13 of which took place on June 10. The F-15 squadron had flown 316 sorties in the six days.

The last three Peace Fox II F-15s were not delivered until the end of August 1982 because of an embargo, unsurprisingly, put in place by the Democratic Carter Administration.

After the Lebanon War, Peace Fox III followed involving nine F-15C and two F-15D aircraft which, once delivered, completed The Point of the Spear Squadron's fleet.

Given the greater performance and better weapon systems, the F-15C and F-15D Baz 2 and Baz 3 fighters soon became 'tip of the spear' of the Israeli Air Force. A status underwritten by further aerial victories against Hafez al-Assad's Soviet-built MiG-23s and MiG-25s in three clashes. On November 19, 1985, F-15C 840 and F-15D 957 downed three Syrian MiG-23s, bringing the number of aerial victories scored by the Baz to 50.

After the 1982 Lebanon War, the availability of two F-15 squadrons led the Israeli Air Force to assign specialised tasking for each of them. The Knights of the Twin Tail Squadron was assigned air defence and air superiority, and a secondary reconnaissance role thanks to the integration of the Ophir reconnaissance pod carried on the ventral station of some two-seater aircraft. The Point of the Spear Squadron was the Baz operational conversion unit, and charged to develop long range attack capability, thanks to the use of Conformal Fuel Tanks on F-15B, F-15C and F-15D models, integration of 2,000lb GBU-15 precision-guided bombs, and aerial refuelling support provided by Boeing 707 tankers introduced into service in 1983.

Around the Middle East region, the threats posed to Israel had reduced in Egypt, Jordan, and Lebanon, but had increased in Iraq, Libya, and Tunisia.

In 1985, Israeli Air Force F-15s conducted another difficult combat mission. At 08:00 local time on October 1, eight F-15s took-off from Tel Nof bound for Hammam-al-Shatt, Tunisia, to carry out the longest attack mission in the history of the Israeli Air Force. Their target was the PLO Headquarters, selected as reprisal for the killing of three Israeli citizens on a yacht in the waters near Cyprus on September 25. The operation was given the mission name Operation Wooden Leg.

Supported by a Boeing 707 tanker, the F-15s conducted multiple air refuellings during the three-hour, 2,160nm transit to the target.

In the attack, the two F-15Cs each delivered six Mk82 bombs, while each of the six two-seat F-15s released a single GBU-15 precision-guided munition, each coupled to an AXQ-14 data-link pod. The target was destroyed, with the death of up to 70 people, many reported by Israeli intelligence as PLO members. However, many others were injured including innocent Tunisians. President Reagan did not condone the attack, and under a resolution, the United Nations Security Council Resolution condemned the attack as a flagrant violation of the UN Charter. Justifying the attack, the Israeli government played the self-defence card.

After a fatal mid-air collision between two F-15As on August 15, 1988, the Baz fleet was reduced to 46 aircraft, which led the Israeli Air Force to acquire attrition replacements: five F-15Ds were ordered under the Peace Fox IV foreign military sale programme. The first jets were delivered on May 4, 1992.

One Wing

Mid-air collisions can rarely be described as legendary. One can be.

According to the Israeli Air Force, on May 1, 1983, Major Ziv Nedivi and Colonel Yehoar Gal took off for a DACT training mission over the Negev desert in southern Israel. Nedivi was flying the lead jet of two F-15 fighters tasked with thwarting a simulated enemy attack by

During their recovery to Ramon, neither Major Nedivi or Colonel Gal could see the missing right wing because it was obscured by fuel and vapour spewing from the aircraft's tanks.

BELOW: ***The buzzard tail marking painted on the outer surface of the vertical stabiliser was adopted in 2002 to denote that the aircraft is modified under the Baz Avionics Upgrade Programme.*** *Riccardo Niccoli*

ABOVE: ***Close-up of F-15D Baz 733 on take-off from Tel Nof showing the radome aft of the canopy which houses the antenna for a satellite communication system.*** *Riccardo Niccoli*

RIGHT: ***F-15D Baz 970 parked within a hardened dispersal at Tel Nof Air Base fitted with conformal fuel tanks, missile launcher rails and a satellite communication system radome aft of the cockpit.*** *Riccardo Niccoli*

an A-4 Aylt (Eagle) Skyhawk aircraft. The beginning was routine. They ascended to 13,500ft to simulate firing a missile at the A-4 which was flying upside down while Nedivi's F-15 was 30° nose down. Suddenly, an impact shook the aircraft. The Skyhawk had climbed until accidently hitting the wing of Nedivi's F-15. The Skyhawk exploded and its pilot managed to eject and safely land. For the Baz however, the situation continued to deteriorate. The jet began to spin uncontrollably. Nedivi engaged the afterburner after which the F-15 stabilised in level flight and diverted for an emergency landing at nearby Ramon Air Base. The F-15 landed at 260kts, nearly twice the normal speed since slowing down would cause them to lose control. Nedivi said: "We landed. I heard the other pilot say over the internal communication: 'You will not believe what you just flew in'." When they raised the canopy, they both realised for the first time that they had flown a plane with one wing. Nedivi later said: "I probably would have ejected had I known that we were flying without a wing."

During their recovery to Ramon, neither Nedivi or Gal could see the missing right wing because it was obscured by fuel and vapour spewing from the aircraft's tanks.

The fighter was transported by road to the Israeli Air Force Aircraft Maintenance Unit at Tel Nof, where it was repaired to flying condition. Engineers remarked that in such a condition, the Eagle should not have been able to fly, let alone land.

Acquiescence and Reward

Following the Iraqi invasion of Kuwait in August 1990, the Israeli Air Force was held at its highest alert status. Once Operation Desert Storm started, Israeli Air Force F-15s were committed to 24/7 Combat Air Patrol missions, to protect the country. Despite Saddam Hussein's efforts to involve Israel in the war by launching Soviet-made Scud-B missiles on Israeli towns, Tel Aviv maintained its armed forces purely at a defensive posture. Given the possibility that Iraqi Scud missiles might be armed with chemical warheads, aircrews and maintenance technicians were forced to wear uncomfortable anti-NBC suits.

Between January 19 and February 25, 1991, Iraq launched 40 Al-Hussein missiles, a local derivative of the R-17E Scud-B, which led to the deaths of more than 70 Israeli civilians.

After the first Iraqi missile launch on January 19, the Israeli government came very close to launching F-15Bs and F-15Ds assigned to The Point of the Spear Squadron in a reprisal attack. The mission was cancelled at the point when aircrews were already sat in the cockpits of their aircraft. The Israeli government acquiesced to US pressure not to retaliate and after the US had promised to hunt down the Scud launch systems, and immediately provide Israel with MIM-104 Patriot surface-to-air missile batteries.

The heavy commitment by the Baz force was reduced from February 12, when the Iraqi threat was much reduced.

To reward the Israeli government's conduct during Operation Desert Storm, the Bush administration also promised delivery of new armaments, including a batch of 25 F-15A and F-15B fighters drawn from US Air Force stocks. However, the aircraft were not delivered in time to defend against the Iraqi threat. Under the Peace Fox V foreign military sale programme, the jets arrived in Israel between October 23, 1991 and June 1992. All 25 were sent to the AMU at Tel Nof for upgrade to the latest Baz standard, including the integration of

Israeli-made avionics, communication, and electronic warfare systems.

The Israel government gave priority to increasing its long range strike aircraft fleet. Consequently, the upgrade programme started with six F-15Bs, the first of which, serial 109, was introduced into service in 1993.

Improving the Baz

Based on the strike requirements the country had faced during Operation Desert Storm, the Israeli Air Force opted to improve the Baz fleet. This was achieved by integrating the Rafael Popeye stand-off air-to-ground missile, a 3,000lb weapon, which has an electro-optical precision-guidance system, and a range of more than 49nm.

In 1994, the new infrared-guided Rafael Python 4 short range and AIM-7M/AIM-7P medium range air-to-air missiles were also integrated on the Baz.

That year, the Israeli government announced its plan to acquire the F-15I Ra'am (Thunder), the Israeli version of the F-15E Strike Eagle. This provided the opportunity to launch an Israeli-led modernisation programme, with the objective of standardising the fleet by introducing new Israeli sub-systems on the Baz and the Ra'am, and to save cost.

A contract for Baz modernisation called Baz Meshopar (Improved Baz) or Baz Avionics Upgrade Programme (AUP) was signed in August 1995 and contracted IAI Lahav Division, Elbit Systems, Boeing (for the re-design of the hardpoints), Hughes (radar upgrade), Honeywell and Loral. Except for the four FSD jets, the AUP involved all F-15A, F-15B, F-15C and F-15D aircraft. The Baz AUP included:

- A new main computer.
- A new armament computer.
- Greater cooling capacity.
- New Elbit multi-function colour displays.
- New Hands-On-Throttle-And-Stick (HOTAS) controls.
- An integrated INS/GPS navigation system.
- A RADA datalink.
- An Elisra self-defence and electronic warfare suite.
- New secure voice radios.
- An upgraded APG-70I standard radar as per the F-15I.
- A MIL-STD-1553 data bus.
- New wiring to the hardpoints.
- The AIM-120 AMRAAM air-to-air missile.
- Additionally, the two-seat F-15Bs and F-15Ds received:
- A MIL-STD-1760 data-bus for the use of new GPS-guided armament, such as the JDAM bombs.
- HOTAS controls and two colour MFDs in the back seat, to allow the navigator to use the self-defence systems, and the air-to-ground weapons.

All modification work was carried out by the AMU centre at Tel Nof. Modification work required 9,000 man hours per aircraft, and when carried out with an overhaul, a further 9,000 hours. Each aircraft was on the modification line for about seven months. Given the different internal configurations of the F-15 variants involved, some airframes were challenging to modify, primarily because of a lack of internal space.

First to roll-out of the modification line at Tel Nof was F-15D serial 706, which was delivered in November 1998. It was then flown to Eglin Air Force Base, Florida for radar and armament testing. The final aircraft, F-15D serial 280, was returned to front line service in November 2005.

Since then, the Israeli Air Force has continued to upgrade its Baz aircraft to include integration of the Elta EL/L-8222 electronic countermeasures jammer pod, the DASH 4 helmet, the Python 5, and the Rafael radar-guided Derby air-to-air missiles.

Many F-15B and F-15D aircraft also received (together with the F-15I) a satellite communication system and an antenna housed in a dome, radome located behind the cockpit canopy.

To date, the Israeli Air Force has taken delivery of 81 F-15 Baz aircraft. At least 12 F-15A models have been retired from service and used as gate-guards, monument displays, training

LEFT: ***Two shots of Major Ziv Nedivi and Colonel Yehoar Gal's F-15 Baz missing its right wing as a result of a mid-air collision with an A-4 Ayit aircraft during dissimilar air combat training over the Negev desert on May 1, 1983.*** *Israeli Air Force*

airframes, or held in storage at Ovda for restoration to flying condition in a crisis or emergency situation.

The Knights of the Twin Tail Squadron operates a mix of F-15A, F-15B and F-15D airframes, while The Point of the Spear Squadron has F-15C, F-15B and F-15D aircraft. At least four Baz aircraft are held on Quick Reaction Alert 24/7, fully armed and ready to launch in minutes to defend Israeli airspace.

Military Aid

On September 14, 2016, the US and Israeli governments signed a $38bn military aid package, the largest in history. Among the many components of the deal was the transfer of ten two-seat F-15D Eagles, dubbed excess defence articles, previously operated by the Oregon Air National Guard's 173rd Fighter Wing - the F-15 Eagle formal training unit based at Klamath Falls.

The Israeli Air Force was especially interested in acquiring two-seat F-15s for conversion to multi-role, long range strike aircraft. Five of the aircraft acquired from the US Air Force replaced older single-seat F-15s with near-expired service lives which were approaching retirement. Each aircraft took nearly six months to modify, a less than straightforward process given the configuration of the American jets and

Israeli F-15 Baz

FMS Program Name	Quantity	Variant	Serial number range
Peace Fox 1976-1978	4	F-15A FSD	600
	19	F-15A	600
	2	TF-15A (F-15B)	400
Peace Fox II 1981-1982	9	F-15C	800
	2	F-15D	400
	4	F-15D	900
Peace Fox III 1985	9	F-15C	500
	2	F-15D	200
Peace Fox IV 1992	5	F-15D	700
Peace Fox V 1991-1992	19	F-15A	300
	6	F-15B	100

the sheer number of new components, Israeli and US, installed.

Given the upgrade history of the Baz fleet and its expected out-of-service date expected a couple of decades in the future, it's likely the aircraft will undergo further upgrades including new display interfaces, upgraded radar and electronic warfare systems, and integration of new air-to-ground weapons. Such upgrades will equip the aircraft with the level of self-protection systems required to counter emerging threats, the necessary networking with other Israeli Air Force aircraft, not least its growing inventory of F-35 Adir fighters.

RIGHT: ***Major Ziv Nedivi and Colonel Yehoar Gal pose for the camera in front of their F-15 without its right wing at Ramon Air Base.*** *Israeli Air Force*

BELOW: ***Three F-15D Baz fighters assigned to The Point of the Spear Squadron on the runway at Decimomannu Air Base, Sardinia, each painted with red arrow markings on the inner surface of the vertical stabiliser, markings adopted in 1991. Aircraft 979 is loaded with an Elta EL/L-8222 electronic countermeasures pod carried on the forward fuselage station.*** *Riccardo Niccoli*

Israel's STRATEGIC STRIKER

Mark Ayton describes Israel's very own Strike Eagle, the F-15I Ra'am

MAIN PICTURE: *F-15I Ra'am 241 seen landing at Nellis Air Force Base, Nevada with the air brake deployed.* Dan Stijovich

All Israel Air Force F-15I Ra'am (Thunder) aircraft are assigned to The Hammers Squadron based at Hatzerim Air Base in the desert region of southern Israel. F-15I aircraft are finished in a split paint scheme; top surfaces are finished in a three-colour camouflage while the under surfaces are in air superiority grey.

The Israeli government's decision to procure a batch of Strike Eagles was driven by the need to equip the air force with a dedicated long-range strike aircraft. During Operation Desert Storm in 1991, when Israel was under attack by Scud missiles launched from Iraq, had Tel Aviv not acquiesced to US pressure not to retaliate, it would have required an aircraft to strike the missile sites located deep inside Iraq.

Two years after the conflict, the Israeli Air Force issued a request for information pertaining to the acquisition of enough multi-role fighter aircraft to equip two squadrons. With the blessing of the US government, Lockheed Martin offered the F-16 while McDonnell Douglas offered a bespoke version of the F-15E Strike Eagle specifically configured to Israeli requirements. The Israeli Air Force carefully evaluated the proposals and soon decided. On January 27, 1994, the Tel Aviv government announced it intended to procure the McDonnell Douglas jet, by then designated the F-15I. The US government quickly approved the deal and signed a letter of offer and acceptance with the Israeli government on May 12.

Foreign Military Sale

The deal involved 21 F-15Is supplied under the Peace Fox V foreign military sale programme with an option for four more supplied, if exercised by Israel, under Peace Fox VI. The Israeli government exercised that option in November 1995. McDonnell Douglas' plant at St Louis, Missouri commenced production of the F-15I and completed the first aircraft during the summer of 1997. That jet made the variant's first flight from Lambert Field on September 12, followed by the arrival in Israel of the first jet on November 6. That said, the first F-15Is were delivered to Hatzerim during January 1998, with follow-on deliveries extending through September 1999 when the 25th jet touched down at its new base. Eight months earlier on January 11, the F-15I flew the variant's first combat sortie over Lebanon in support of the conflict with the Iranian-sponsored radical Lebanese Shia organisation, Hezbollah. Since then, F-15Is have participated in numerous Israeli military operations that include the 2006 Lebanon War; Operation Cast Lead in the 2008 Gaza War; Operation Pillar of Defence in November 2012; Operation Protective Edge in the 2014 Gaza War and through to the present day, numerous covert airstrikes with

ABOVE: ***Three F-15I Ra'am aircraft await clearance to launch at Uvda Air Base, Israel during the bi-lateral exercise Juniper Falcon.*** *US Air Force/TSgt Matthew Plew*

BELOW: ***F-15I Ra'am 217 loaded with a heavy precision-guided munition, an AAQ-13 targeting pod (nearside) and an AAQ-14 navigation pod at Hatzerim Air Base.*** *Israeli Air Force*

The first F-15I arrived in Israel on November 6, 1997.

F-15I Ra'am Sub-Systems

F-15I hosts a number of Israeli-made sub-systems:
- A central computer.
- Communication systems.
- A GPS/inertial guidance system.
- An Elisra SPS-2110 Integrated Electronic Warfare System in place of the American Tactical Electronic Warfare Suite.
- Radar warning receivers.
- Additional upward-firing chaff and flare dispensers on the upper surface of the rear fuselage.
- An Elbit DASH display and helmet-mounted sight (DASH). Also, all of the aircraft's sensors can be slaved to the DASH sight.

American sub-systems include:
- Raytheon's APG-70 terrain-mapping radar.
- Lockheed Martin's navigation and targeting system used for all weather precision attack.
- Lockheed Martin's AAQ-13 LANTIRN targeting pod.
- Lockheed Martin's AAQ-14 LANTIRN navigation pod with a terrain-following (TF) radar. The pod's TF and FLIR feeds are both fed to the
- DASH head-up display. LANTIRN pods enable
- NVG-compatible cockpits.
- Two Pratt & Whitney F100-PW-229 turbofan engines.

Air-to-air missiles integrated on the F-15I include:
- Raytheon's AIM-9L Sidewinder though this missile has given way to the Python.
- Raytheon's AIM-7 Sparrow.
- Raytheon's AIM-120 AMRAAM.
- And the Israeli Rafael Python 4, a high off-boresight short-range missile targeted with the DASH helmet-mounted display.

Air-to-ground munitions integrated include:
- AGM-88 HARM high-speed anti-radar missile.
- BLU-109 hard target penetrator warhead.
- Joint Direct Attack Munitions.
- Paveway-series laser-guided bombs.
- Israeli Rafael SPICE-series precision-guided munition.

TOP RIGHT: ***F-15I Ra'am 269 assigned to The Hammers Squadron banks away from a KC-135 Stratotanker over Nevada's Test and Training Range during an air interdiction mission in Exercise Red Flag.*** *US Air Force/TSgt Kevin Gruenwald*

stand-off weapons against targets in Syria, reported to be run by Hezbollah.

Ra'am Upgrade

In early 2016, the Israeli government approved an upgrade programme for the F-15I, one designed to sustain the aircraft as one of the Israeli Air Force's primary strike types. The upgrade programme includes structural modifications, the Raytheon APG-82(V)1 active electronically-scanned array radar, updated avionics, and as yet new, unspecified weapons.

Furthermore, in the third week of September 2018, the Israeli Air Force reportedly requested information about procuring 25 new F-15IA Advanced Eagles and upgrading its F-15Is to F-15IA standard over the next decade. If a contract is eventually signed, the jets would further increase the existing F-15 strike fleet and increase the Israeli Air Force's capability to attack long range targets. The nascent F-15IA is reported to offer several advantageous capabilities by comparison to the existing F-15I that include greater range and survivability, advanced avionic systems, a 26,000lb payload that can include up to 11 missiles of various types and 28 precision-guided bombs, and the ability to carry and employ all types of air-launched weapon in the Israeli Air Force arsenal. If ordered this year, the first F-15IA could arrive in Israel during 2023, but the Israeli government's appetite for buying more F-15 Strike Eagles in addition to a third squadron of F-35 Adir fighters remains in the balance.

Dan Stijovich

Japan's EAGLES

Mark Ayton details the F-15J Eagle, licence-built in Japan for the Japan Air Self Defense Force. Additional details by **Mike Yeo.**

1980s Japan built some 200 F-15s under licence from McDonnell Douglas and they are currently operated by seven operational squadrons, a training squadron, and a dedicated aggressor unit.

The latter is an especially interesting unit, operating approximately a dozen two-seat F-15DJs painted in a variety of colourful camouflage schemes. These Aggressor F-15s deploy from their base at Komatsu in western Japan to the different combat air bases several times a year to conduct air combat training with resident units.

Like the JASDF's other combat types, Eagles come under the Air Defense Command and are assigned to the respective Air Defense Force of the four regional headquarters. Two F-15 Hikotai (squadrons) are each assigned to the Northern, Central and Southwestern Air Defense Forces, respectively.

Okinawa-based Southwestern Air Defense Force only gained its second F-15J unit in 2015, when 304 Hikotai relocated from Tsuiki Air Base to Naha, along with a detachment of Northrop-Grumman E-2 Hawkeye airborne early warning aircraft from Misawa, in response to increasing Chinese military aircraft activity.

However, an upgrade programme contracted to Boeing at a cost of 39 billion that would have involved 98 F-15Js upgraded in the coming years to F-15JSI (Japan Super Interceptor) standard was cancelled by the Japanese Ministry of Defence in early April. The upgrade programme was intended to include a new active electronically scanned array radar, mission computer, improved electronic warfare and other systems including integration of the Lockheed-Martin AGM-158 Joint Air-to-Surface Standoff Missile. The change of policy is significant as had the upgrade gone ahead, it would have marked the first time a Japanese combat aircraft had been equipped with a strike capability.

Japan's F-15 Requirement

In the mid-1970s, the JASDF needed a replacement fighter for its entire fleet of F-104J Starfighters and part of its fleet of F-4EJ Phantoms. Dubbed the FX-3 programme, a cost estimation was included in the FY1975 budget proposal submitted in 1974. The FX-3 selection programme involving 13 types started in 1975. In 1976, seven types remained in the running: the Grumman F-14, the McDonnell Douglas F-15,

BELOW: ***F-15DJ 82-8091 on final approach with the dorsal air brake deployed. Like most of the F-15s assigned to the Hiko Kyodotai, the aircraft is painted in a three tone colour scheme comprising green, black and grey. It's likely the unusual choice of colours used by the unit's aircraft replicates landscapes around Japan.*** *Dan Stijovich*

RIGHT: ***F-15DJ 92-8068 is assigned to the Hiko Kyodotai (Tactical Fighter Training Group) based at Komatsu Air Base. The unit is dedicated to providing adversary fighter support to all JASDF fighter squadrons. This jet is painted in a two-tone blue and grey colour scheme.*** *Dan Stijovich*

General Dynamics' F-16, Northrop's F-17, the Dassault Mirage F1, Saab's JAS 37 Viggen and the Panavia Tornado. Based on the JASDF evaluation, the F-14, F-15, and F-16, were shortlisted but the F-16 was subsequently dropped because it did not offer the JASDF with day-night, all weather capability. The two types still standing were the US Navy's Grumman F-14 Tomcat and the US Air Force's F-15 Eagle.

By December 1976, the F-15 was the JASDF's preferred choice based on its rate of climb, acceleration, its prowess in air-to-air engagements, and its life-cycle cost.

Following a meeting of the Japanese National Security Council (NSC) on December 21, 1976, a formal decision was postponed for one year. The NSC citing insufficient time for proper deliberation and inclusion in the FY1977 budget. Subsequently, the green light for the F-15 was made on December 28, 1977.

Japan's F-15 aircraft were supplied under the US Peace Eagle foreign military sale programme. The licence production agreement between Mitsubishi Heavy Industries (MHI) and McDonnell Douglas was signed, with the understanding that funding for 23 aircraft would be allocated in the FY1978 budget, which was adopted in late March 1978.

LEFT: *F-15DJ 92-8095 on take-off from Nyutabaru Air Base with the afterburners engaged. At first glance, this aircraft appears to have a colour scheme comprising four different colours. In fact, specific areas of the aircraft's surfaces are painted with a camouflage comprising black, blue, and brown.* Dan Stijovich

In the spring of 1978, Mitsubishi engineers arrived at the McDonnell Douglas plant in St Louis to organise a plan to produce the F-15 under licence in Japan, and to oversee the production of jigs and tooling and assembling knockdown kits for shipment to Japan for aircraft assembly.

Later that year, McDonnell Douglas engineers arrived at MHI's Komaki facility to oversee the production of parts approved for domestic production.

The first F-15J was handed over to the JASDF at the McDonnell Douglas plant in St Louis in July 1980 and entered a flight test programme at Edwards Air Force Base, California, which was completed that October.

Initial JASDF aircrew training was conducted at Luke Air Force Base, Arizona and some maintenance personnel were trained at Eglin Air Force Base, Florida. During their tenure in the United States, JASDF pilots and engineers visited Edwards Air Force Base, California, to participate in the testing of the F-15J's flight performance, radar, and data link systems. US Air Force aircrews delivered the first two F-15Js to Japan on June 1, 1981 landing at Gifu Air Base where the aircraft were handed over to the JASDF.

Initially the NSC authorised procurement of 100 aircraft over a ten-year period. However, additional orders followed in 1982 (55), 1985 (32), and 1990 (36) for a proposed total force of 223 aircraft. Under the NSC's, then latest, 1992 defence force development plan, numbers were reduced to 210 and

subsequently increased by three aircraft in 1995.

The first two F-15J and the first 12 F-15DJ aircraft were built at McDonnell Douglas' St Louis facility and flown by delivery flights to Japan. Ten F-15J and eight F-15DJ aircraft were then supplied as kits and re-assembled by MHI at Komaki while the remaining 153 F-15Js and 28 F-15DJs were assembled by MHI with Japanese-produced components.

MHI was responsible for building the forward and mid-fuselage sections, Kawasaki Heavy Industries built the aft fuselage section, the main wing, and the horizontal and vertical stabilisers. Fuji Heavy Industries produced the nose landing gear and the main landing gear doors; the main landing gears were produced by Sumitomo Precision Products.

The final, 165th, F-15J was rolled-out at Komaki on November 4, 1998 followed by the final, 48th, F-15DJ on October 25, 1999. Japan's final F-15 procurement cost was JPY10.156 billion, and by the end of October 1999, the JASDF had the second largest F-15 fleet in the world after that of the US Air Force. As of March 2020, 201 F-15s remained in JASDF service.

BELOW: *This shot of F-15DJ 52-8088 clearly shows how the camouflage schemes used by the Hiko Kyodotai are applied to specific areas of the aircraft's surfaces as opposed to the entire airframe. The Hiko Kyodotai is assigned to the Koku Senjyutsu Kyododan (Tactical Air Training Command).* Dan Stijovich

F-15J Service Introduction Chronology

Squadron	Air Base	Activation date
203 Hikotai	Chitose	March 24, 1984
204 Hikotai	Hyakuri	1985
201 Hikotai	Chitose	March 1986
303 Hikotai	Komatsu	December 1, 1987
304 Hikotai	Tsuiki	January 20, 1990
305 Hikotai	Hyakuri	August 2, 1993
306 Hikotai	Komatsu	March 18, 1997
202 Hikotai	Nyutabaru	Disbanded October 3, 2000
23 Hikotai		October 3, 2000
Flight Guidance Corps	Nyutabaru	August 1, 2014 re-designated from the Flight Guidance Corps
204 Hikotai	Relocated to Naha	January 19, 2009
Tactical Fighter Training Group	Nyutabaru	August 1, 2014 re-designated from the Flight Guidance Corps
204 Hikotai	Relocated to Naha	January 19, 2009 and incorporated into 83 Hikotai
83 Hikotai	Naha	De-activated January 31, 2016
304 Hikotai	Relocated to Naha	January 31, 2016
Tactical Fighter Training Group	Relocated to Komatsu	June 10, 2016
305 Hikotai	Relocated to Nyutabaru	August 31, 2016

Service Introduction

Following the JASDF's 202 Hikotai (squadron) activation as the F-15 conversion training unit at Nyutabaru Air Base on December 21, 1981, the type's service introduction was successfully implemented. Up until 2009, the fleet was assigned to the squadrons and bases the aircraft had originally been sent to. However, the panel above charts the original F-15 squadron allocations and more recent changes.

F-15J Configurations

Japan's single-seat F-15J is based on the US Air Force F-15C and the two-seat F-15DJ on the American F-15D. However, JASDF Eagles do differ to their US Air Force counterparts in configuration terms with use of Japanese manufactured systems including: the JTEWS Tactical Electronic Warfare System, J/ALQ-8 jammer (not carried by the F-15DJ), J/APR-4 radar warning receiver, J/ASW-10 data link and the ALE-45J countermeasures dispenser system.

Aircraft up to serial number 42-8944 are powered by F100-IHI-100 turbofan engines, a licenced-built version of the Pratt & Whitney F100-PW-100 produced by IHI, Japan's leading maker of jet engines. All aircraft from serial number 42-8945 are powered by F100-IHI-220E engines. Many of the original aircraft have been retrofitted with -220E engines.

Armed for the air superiority mission, JASDF F-15s carry Mitsubishi AAM-3, AAM-4 and AAM-5, and Raytheon AIM-9 Sidewinder and AIM-7 Sparrow air-to-air missiles and a JM61A1 20mm Vulcan cannon.

Visually, the F-15J does have some slight differences in its appearance to the F-15C, lacking an electronic warfare system antenna and an electronic countermeasure pod fitted on the left vertical stabiliser.

Aircraft delivered between 1981 and 1984 were configured to standard called Pre-Multi-Stage Improvement Program (MSIP), a progressive upgrade programme implemented by the US Air Force on its fleet of F-15A and F-15B aircraft. MSIP II was applied to F-15C and F-15D aircraft, the standard replicated in the Japan-Multi-Stage Improvement Program (J-MSIP), the design of which started in 1997.

F-15s configured to J-MSIP standard feature an improved APR-1R central computer with greater processing capacity, a new AWG-20 fire control radar set (and subsequently the AWG-27), a new MPCD weapon control panel and ARC-182 radio, a MIL-STD-1553B data bus and F100-IHI-220E engines with Full Authority Digital Engine Control and improved durability.

An additional upgrade was undertaken on J-MSIP aircraft, one designed to provide operational capability of AAM-4, AAM-4B, AAM-5 and AIM-120 air-to-air missiles. The upgrade included updated OFP software for the central computer and radar, a new AWG-27 fire control radar set, a new J/ARG-1 missile command guidance system, and a modified LAU-106A/A missile launch rail.

The first F-15J, serial number 12-8928, was delivered to MHI at Komaki in 2002. Configured to J-MSIP standard, aircraft 12-8928 made its first flight on July 24, 2003 and was delivered to the Gifu-based Air Development and Test Wing for flight testing on October 21.

By 2019, 100 JASDF F-15s had entered the modernisation programme, of which 92 had been delivered.

South Korea's STRATEGIC STRIKER

Mark Ayton details the F-15K Slam Eagle in service with the Republic of Korea Air Force.

If you lived next door to a bully that wanted what you had, you'd take precautions. That's the situation for the Republic of Korea. They share a land border with a hermit kingdom that's governed by a totalitarian dictatorship armed with nuclear weapon sites and hardened command and control facilities. For peace of mind South Korea needs the ability to strike such targets. On the Korean peninsula, the Democratic People's Republic of Korea led by 'supreme leader' Kim Jong-un presents the Republic of Korea with exactly that scenario. Today the Republic of Korea Air Force (RoKAF) operates a fleet of 60 F-15K Slam Eagles each capable of striking North Korean missile, artillery and nuclear sites, and command and control facilities.

Built by Boeing Defense at its St Louis, Missouri facility, the original home of McDonnell Douglas and the F-15 Eagle, Boeing reckons the F-15K integrates the proven F-15 airframe with advanced avionics and electronics that provide exceptional situational awareness and razor-sharp precision targeting—in any weather, day, or night. Furthermore, the F-15K combines enhanced air-to-air, air-to-ground, and maritime strike capabilities.

In June 2002, the Republic of Korea ordered 40 F-15Ks and a weapons package valued at $3.6bn to meet its requirements for the first phase of its three-phase F-X programme as replacements for ageing F-4D Phantoms. F-15K deliveries began in 2005 and concluded in August 2008, the year the Republic of Korea ordered a second batch. This comprised 21 F-15Ks as a replacement for ageing

MAIN PICTURE: ***Four F-15Ks in formation over an island in the Sea of Japan during a mission from Daegu Air Base.*** *Republic of Korea MND*

TOP RIGHT: ***F-15K 02-039 seen landing at Nellis Air Force Base, Nevada during Exercise Red Flag in August 2008.*** *Paul Ridgway*

BOTTOM MIDDLE: *RoKAF maintainers work on a radar warning receiver sensor.* Paul Ridgway

BOTTOM RIGHT: *F-15K aircrews hold on the end of the runway ramp while awaiting clearance to taxi at Nellis.* Paul Ridgway

F-5B Freedom Fighters. The 21st aircraft was an attrition replacement for an aircraft lost in 2006.

A big factor in the contracts awarded to Boeing for F-15Ks was the level of components (nearly 40%) produced by South Korean sites and supplied to Boeing for final assembly in St Louis.

Korea Aerospace Industries supplied wings and forward fuselages for 32 F-15Ks. Hanwha Corporation supplied hydraulic and flight control actuators. Doosan DST developed the GPS/INS systems, electronic systems and radar warning receiver components were supplied by Samsung Thales, and landing gear components by WIA.

Since 2012, Boeing has been responsible for sustainment of the F-15K fleet under rolling five-year term performance-based logistics contracts, the second of which was awarded in March 2017. In country logistics and supply chain distribution are undertaken by Hyundai Glovis in partnership with Boeing.

Systems

Boeing's advanced cockpit fitted in the F-15K features a new configuration and new cockpit display technologies that provide advanced navigation and weapons data information to the aircrew.

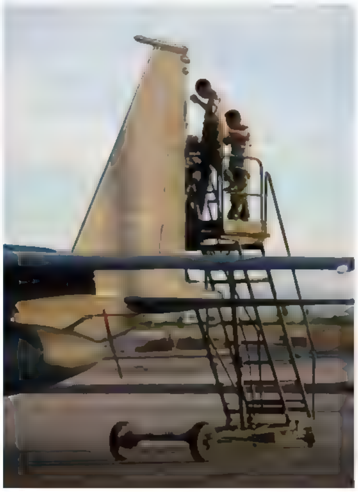
The suite of Kaiser Electronics displays comprises three flat panel colour displays, four multi-purpose displays, two upfront control panels, a wide field of view head-up display, compatible with night-vision goggles and a Joint Helmet Mounted Cueing System.

Slam Eagles are fitted with the Honeywell Advanced Display Core Processor, the aircraft's mission computer with ten times the processing capability of the processor installed in the original F-15E.

Raytheon's APG-63(V)1 radar with a simultaneous 14-target tracking, and 6-track targeting capability. Types include high, low, ground moving and sea surface targets, plus high-resolution ground mapping capability for identifying targets at long ranges with 10 times more computing power than its predecessor.

Boeing's Tactical Electronic Warfare Suite is the primary self-protection system, and it integrates several components including:

- BAE System's ALR-56C(V)1 radar-warning receiver.
- Northrop Grumman's high-power ALQ-135M countermeasure system with faster processors that track and jam multiple incoming surface-to-air-missiles.
- BAE System's ALE-47 chaff/flare countermeasure dispenser system which releases chaff and flare decoys timed and aimed to achieve maximum confusion to threat missiles.
- Lockheed Martin's AAS-42 infrared search-and-track system, which enables the aircraft to detect aircraft at shorter ranges without activating the radar.



- Link 16 datalink which provides inter-plane data sharing without the need for voice communications thereby reducing vulnerability of detection by an enemy.
- Joint Helmet-Mounted Cueing System enables the pilot to move his or her head with auto slaving of the missile's seeker enabling the pilot to remain in a defensive position.
- Lockheed Martin Sniper XR targeting pods.

Engines

With a maximum gross take-off weight of 81,000lb, the F-15K needs two powerful engines to haul heavy weapon payloads and achieve high-performance, not least a maximum speed of Mach 2.5 and terrain-following flight at a minimum altitude of 100ft at Mach 0.93.

Unusually, the RoKAF opted for a different type of engine for each of the two batches of F-15Ks procured. The first batch of 40 aircraft are powered by GE Aviation F110-GE-129A turbofan engines, each rated at 29,000lb, while the second batch of 21 aircraft are powered by Pratt & Whitney F100-PW-229 EEP turbofan engines, each rated at 29,100lb and common with the RoKAF's KF-16 fleet.

Weapons

The F-15K is designed to conduct long-range day or night precision strike missions in all weather conditions armed with a maximum weapons payload of 23,000lb comprising a mix of air-to-air, air-to-ground and stand-off missiles including:

- AGM-84D Harpoon Block II maritime strike missile.
- AGM-84E Standoff Land Attack Missile–Expanded Response (SLAM-ER) long-range air-to-ground missile. The F-15K was the first Eagle variant to release an AGM-84E SLAM-ER missile over the Pacific Missile Range off the coast of southern California in March 2006. The Slam Eagle name was derived from the SLAM-ER missile.
- AIM-9X Sidewinder and AIM-120 AMRAAM air-to-air missiles.
- GBU-38-series 500lb Joint Direct Attack Munitions. The F-15K is the first F-15E variant capable of carrying up to 12 GBU-38s on the aircraft's conformal fuel tanks stations — twice as many as the F-15E.
- KEPD 350K Taurus conventionally armed stand-off missiles; the RoKAF's biggest stick with which, in the event of war, to destroy North Korean missile

ABOVE: ***F-15K 02-035 on final approach to Nellis bathed in golden Nevada light on a late August afternoon. Note the AAQ-14 LANTIRN targeting pod fitted on the right side forward fuselage pylon.*** *Paul Ridgway*

BELOW: ***F-15Ks taxi to the end of runway ramp at Nellis prior to departure on a night-time Red Flag mission.*** *Paul Ridgway*

F-15K Milestones

April 2003
Boeing began assembly of the first central fuselage

October 2004
Final assembly completed

March 3, 2005
F-15K maiden flight at St Louis

March 16, 2005
First F-15K roll-out ceremony at Boeing's facility in St Louis. At the ceremony, General Lee Han Ho, the Republic of Korea Air Force Chief of Staff said: "Integration of this multirole fighter into our force will certainly be a great momentum in improving our air power. Moreover, the F-15K will enhance the interoperability between the Republic of Korea and the US Air Force."

April 2005
Boeing accepted the first wing and forward fuselage made by Korea Aerospace Industries (KAI) in Sachon, South Korea. KAI produced components for 32 of the 40 aircraft ordered by the RoKAF with the final assembly conducted in St Louis

October 2005
First two F-15Ks were delivered to the RoKAF during the Seoul Air Show

August 2008
Fortieth F-15K was delivered to the RoKAF during Exercise Red Flag at Nellis Air Force Base, Nevada. All 40 deliveries were officially concluded in October 2008

September 2010
Boeing delivered the first six F-15Ks from the second batch

April 2012
Final two aircraft from the second batch were handed over to the RoKAF at Daegu Air Base

TOP RIGHT: ***F-15K 02-038 moments from touchdown on runway 21R at Nellis.*** *Paull Ridgway*

ABOVE RIGHT: ***Take-off when the aircraft is in a clean configuration is light work for the two GE Aviation F110-GE-129A turbofan engines, each rated at 29,000lb.*** *Republic of Korea MND*

BELOW: ***The angle of this shot clearly shows six weapon stations fitted to the aircraft's conformal fuel tank. This carriage system enables an F-15K to carry 12 GBU-38 500lb JDAM munitions.*** *Paul Ridgway*

silos, command and control facilities and bunkers.

Taurus Systems GmbH, a joint venture of MBDA Deutschland GmbH and SAAB Dynamics AB, handed over the first lot of Taurus KEPD 350K stand–off missiles to the Republic of Korea Air Force on October 14, 2016 at the company's headquarters in Schrobenhausen, Bavaria. The event marked the start of series deliveries.

Measuring 16ft in length and weighing 3,000lb (including a 1,000lb warhead), Taurus KEPD 350K is an enhanced and upgraded version of the KEPD 350 variant, which has been in service with the Luftwaffe since 2005.

The KEPD 350K modular jet-powered stand-off missile is designed and developed to fly just below the speed of sound through dense air defences at a very low terrain-following level (around 130ft above the ground) and for the engagement of high-value targets more than 300 miles away from its launch position.

Its navigation system utilises INS continuously supported by GPS: image based and terrain reference sensors. Dubbed a fail-safe concept designed to enable the system to maintain its planned flight path even without permanent GPS availability.

The dual stage warhead system combines penetration capabilities for high value hard and deeply buried targets and blast fragmentation capabilities for area targets. Equipped with a programmable intelligent multi-purpose fuse enables detonation of the penetrator at pre-selected floors within the target structure through layer counting and void-sensing technologies.

To date, South Korea has 260 of the KEPD 350K missiles in its inventory.

Based in the South

All 60 F-15Ks are assigned to the 11th Fighter Wing based at Daegu Air Base in North Gyeongsang Province alongside the east bank of the River Kumho. Located 170 miles south of the demilitarized zone, the base shares its two parallel runways with Daegu International Airport. The 11th Fighter Wing has three component units each operating the F-15K: the 102nd, 110th and 122nd Fighter Squadrons. Basing the F-15K fleet at Daegu was a strategic decision by the RoKAF based on the distance of the base from the border with North Korea. In the event of conflict with the North, during the initial days of war, F-15Ks could operate from Daegu with impunity. This would enable the jets to launch on long-range strike missions against targets inside North Korea using the 300 mile range advantage of the KEPD 350K Taurus missile to launch attacks from within Republic of Korea airspace.

Given the F-15K's strategic role within the RoKAF, the aircraft are rarely seen outside of the country. That said, F-15Ks have participated in Exercise Red Flag at Nellis Air Force Base, Nevada in August 2008, and January 2012 for multi-national training with US and allied forces.

Middle Eastern MISSILE SHIP

Lon Nordeen, David Isby and **Jon Lake** detail the F-15SA Advanced Eagle in service with the Royal Saudi Air Force.

MAIN PICTURE: *F-15SA 12-1003 is painted in the standard Royal Saudi Air Force paint scheme. The aircraft was one of three assigned to the flight-test programme conducted by the US Air Force's 416th Flight Test Squadron detachment based Air Force Plant 42 at Palmdale, California.* Dan Stijovich

One of the most extensive advances in the F-15 Eagle's design was taken when Saudi Arabia decided to supplement the fleet they'd already got. On December 29, 2011, the nation signed a letter of offer and acceptance for 84 new F-15SA aircraft, plus weapons, support, and training, and for the upgrade of its fleet of F-15S aircraft to F-15SA configuration. The entire programme successfully passed through the required US Congressional review process.

The Royal Saudi Air Force (RSAF) has flown Eagles since the 1978 Peace Sun foreign military sale programme which initiated the sale of 60 F-15C and F-15D aircraft. Those aircraft equipped four squadrons by the late 1980s. In 1993, Saudi Arabia ordered 72 two-seat F-15S aircraft under the Peace Sun IX foreign military sale programme. Deliveries took place between 1995 and 1999 and equipped three more squadrons.

Saudi investment in the F-15 force came at a turbulent time in the Gulf region, where ongoing conflict in Yemen and Iran's nuclear ambitions continue to raise tensions.

Speaking at a briefing on December 30, 2011, Andrew Shapiro, US assistant secretary of state said: "This sale will send a strong message to the countries in the region that the US is committed to stability in the Gulf and broader Middle East. It will enhance Saudi Arabia's ability to deter and defend against external threats to its sovereignty. It will also advance interoperability between the air forces of our two countries through training and joint exercises. And lastly, this agreement will positively impact the US economy. According to industry experts, this agreement will support more than 50,000 American jobs."

Speaking at the same briefing Dr James Miller, deputy undersecretary of state added: "The F-15SA, will be the most capable and versatile aircraft in the Royal Saudi fighter inventory. And indeed, it will be one of the most capable aircraft in the world. The F-15SA will have the latest generation of computing power, radar technology, infrared sensors, and electronic warfare systems. As one example, the F-15SA will be equipped with an active electronically scanned array radar, or AESA. This radar includes the latest technology and will ensure that Saudi Arabia has the capability to operate against regional threats. The communications systems of the F-15SA will allow the US Air Force and Royal Saudi Air Force to operate effectively together in the same airspace. And the systems interoperability will allow both countries to participate in coalition

training, which is a priority for both our countries. And in fact, this F-15SA package includes not just aircraft and munitions but the training and logistics support. Much of the Saudi training in the F-15SA will occur alongside US forces. This will enhance our already strong defence relationship. And approximately 5,500 Saudi personnel will be trained through 2019."

Programme

Manufacture of F-15SA Advanced Eagles to meet the RSAF's order continued even while the flight-test programme was ongoing. A large number of aircraft were completed and test-flown before being stored until the flight-test programme was concluded, at which point the definitive flight control system software was uploaded, and deliveries started.

Boeing is about complete with the new-build aircraft and all surviving Saudi F-15S Strike Eagles will be refurbished and upgraded to the same standard, using US-supplied conversion kits. At the time that the original agreement was signed, this meant that there were to be 70 F-15SA conversions, but attrition since then means that the current number of aircraft to be converted is 68. The first two F-15S-to-F-15SA upgrades were undertaken by Boeing at its St Louis facility. The first phase of the upgrade was due to finish by the end of December 2015, before the second phase of conversions to be carried out in-kingdom began in 2016. These were by the Alsalam Aircraft Company in Riyadh. The company, originally set up as part of a Boeing offset arrangement, received a $33.1m firm-fixed-price contract to set up the required facility, develop manufacturing plans and schedules, and ready automated performance reporting tools.

In total, the RSAF will eventually operate 152 F-15SAs and it represents potentially the most valuable US foreign military sale to date.

The new variant for Saudi Arabia builds on the enhanced F-15K and F-15SG variants built for the Republic of Korea and the Republic of Singapore, featuring further featu followed by the arrival in Israel of the first jet on November 6 res and capabilities. A mark of the F-15SA's advanced configuration lies in the fact that its avionics and systems are largely the same as those adopted for Boeing's now abandoned stealthy F-15SE Silent Eagle project. Consequently, the Saudi F-15SA Advanced Eagle configuration is in many ways more capable than any US Air Force F-15.

Saudi Arabia always seeks to diversify the sources of its military equipment, and it was always expected that the Kingdom would augment its August 2006 purchase of 72 Eurofighter Typhoons with the acquisition of another fighter type, so it was always likely that the nation would turn to the United States to complement the European aircraft.

Saudi attention soon focussed on an advanced version of the F-15; the type was already in RSAF service in F-15C and F-15D fighter and F-15S strike fighter configurations. Furthermore, an order for more F-15s from Saudi Arabia promised to save Boeing's F-15 production line from closure following completion of the production for Korean F-15Ks and Singaporean F-15SGs.

Initially the United States offered a modestly improved F-15S+ configuration featuring F110 engines, the Sniper targeting pod, Link 16 data link, and the APG-63(V)1 radar set. The APG-63(V)1 features a digital back end, married to a mechanically-scanned array. This promised to give a significant performance improvement over the baseline APG-70 radar and provided the ability to fit an electronically-scanned antenna array at a later date.

However, the F-15S+ was too modest a proposal for Saudi Arabia. It is believed that Boeing hoped to sell the stealth-modified F-15SE Silent Eagle to them but this did not happen, though whether this was due to growing US sensitivity over the export of advanced and sensitive technologies or whether it was due to objections by the Israeli lobby is not known.

The original Saudi F-15S, 72 of which were built between 1996 and 1998, was supplied without conformal fuel tanks, and fitted with a radar with a detuned Doppler beam-sharpening capability giving an effective reduction in resolution (to about one third of US Air Force F-15Es) and range. Both downgrades were incorporated to appease Israeli sensitivities.

But with other manufacturers willing to supply more advanced fighters, and with budgetary pressures forcing the United States to reduce its permanent military presence in the Middle East, supplying its regional allies with the 'tools to do the job' gained greater importance. Politically, Saudi Arabia was unwilling to let Israel dictate what equipment it could and could not receive.

Only an F-15SA equipped with an AESA radar set would meet RSAF requirements, while such an aircraft also promised to allow the RSAF a higher degree of interoperability

ABOVE: ***F-15SA 12-1001 is painted with high-visibility dayglo orange surfaces, similar to those applied to the very first F-15A Eagles in the early 1970s.*** *Dan Stijovich*

BELOW: ***Eight Royal Saudi Air Force F-15S Eagles parked on the Nellis flight line during Exercise Red Flag 2012-02.*** *Paul Ridgway*

"The F-15SA, will be the most capable and versatile aircraft in the Royal Saudi fighter inventory."

US Deputy Undersecretary of State in 2011, Dr James Miller

ABOVE: *Seen flying at low-level through a red rock canyon in southern California during a test mission flown from Palmdale, F-15SA 12-1004 was the fourth aircraft built.* Dan Stijovich

with US and allied air forces, while providing capabilities better-tailored for dealing with small, dispersed target sets – exemplified by the dispersed elements of Iran's Islamic Revolutionary Guards Corps (IRGC) and for the kind of asymmetric warfare required for combatting Houthi and Al Qaeda in the Arabian Peninsula and rebels and insurgents on the Yemeni border.

The F-15SA eventually offered to Saudi Arabia was thus the most advanced export version of the aircraft to date. Valued at $29.4bn, the F-15SA package was approved by the US Congress in 2010 and the agreement was signed by President Obama in 2011.

The formal order for the 84 new build F-15SAs was placed in March 2012, while a contract for the conversion of 68 F-15S aircraft to F-15SA standards was placed on 26 June 2012 – two of the original 70 F-15S aircraft having been lost in the interim.

F-15SA Systems

Boeing's advanced cockpit fitted in the F-15SA features a new configuration and new cockpit display technologies that provide advanced navigation and weapons data information to the aircrew.

The suite of Kaiser Electronics displays comprises three flat panel colour displays, four multi-purpose displays, two upfront control panels, a wide field of view head-up display, compatible with night-vision goggles and a Joint Helmet Mounted Cueing System.

F-15SA Advanced Eagles are fitted with the Honeywell Advanced Display Core Processor, the aircraft's mission computer with ten times the processing capability of the processor installed in the original F-15E.

Raytheon's APG-63(V)1 radar with a simultaneous 14-target tracking, and 6-track targeting capability. Types include high, low, ground moving and sea surface targets, plus high-resolution ground mapping capability for identifying targets at long ranges with 10 times more computing power than its predecessor.

Lockheed Martin's AAQ-33 Sniper targeting, and LANTIRN Tiger Eyes navigation pods are also fitted as is their AAS-42 infrared search-and-track system carried in the forward part of the Sniper pylon. The manufacturer reckons the system detects, tracks, identifies, and targets airborne targets at shorter ranges without activating the radar, including those with stealth and radar jamming capabilities.

BAE Systems' digital electronic warfare suite is the F-15SA's self-protection system which integrates BAE System's ALR-56C(V)1 radar-warning receiver, Northrop Grumman's high-power ALQ-135M countermeasure system with faster processors that track and jam multiple incoming surface-to-air-missiles, and BAE System's ALE-47 chaff/flare countermeasure dispenser system. The release of chaff and flare decoys are timed and aimed to achieve maximum confusion to threat missiles.

Link 16-compatible datalink which provides inter-plane data sharing without the need for voice communications is also fitted thereby reducing vulnerability of detection by an enemy.

The Joint Helmet-Mounted Cueing System enables the pilot to move his or her head with auto slaving of the missile's seeker enabling the pilot to remain in a defensive position and ITT AVS-9 night vision goggles are part of the suite.

Additionally, Goodrich DB-110 reconnaissance pods, giving the RSAF a formidable high-definition electro-optical LOROP capability and immediate digital down-link capability are included together with Remotely Operated Video Enhance Receiver (ROVER) terminals for air-to-ground communications.

There are also conformal fuel tanks which provide additional fuel and weapons hardpoints.

Engines

With a maximum gross take-off weight of 81,000lb, the F-15SA needs two powerful engines to haul heavy weapon payloads and achieve high-performance, not least a maximum speed of Mach 2.5. Saudi F-15SAs are powered by two GE Aviation F110-GE-129A turbofan engines, each rated at 29,000lbf.

BELOW: *F-15S 5506 landing on runway 21R at Nellis during Exercise Red Flag 2012-02.* Paul Ridgway

ABOVE: *This photo of F-15S 9223 shows the huge engine nozzles extended for full afterburner power. The combined thrust of the two GE Aviation F110-GE-129C turbofan engines is 58,000lbf.*

Weapons

The F-15SA is designed to conduct long-range day or night precision strike missions in all weather conditions armed with a maximum weapons payload of 23,000lb comprising a mix of air-to-air, air-to-ground and stand-off missiles including:

- AIM-9X Sidewinder and AIM-120 AMRAAM air-to-air missiles.
- AGM-88B HARM High-speed Anti-Radiation Missiles.
- AGM-84 Block II Harpoon maritime strike missiles.
- AGM-84H standoff land attack missiles–extended response (SLAM-ER) air-to-surface missile.
- AGM-154C Joint Stand-Off Weapon (JSOW) which complies with Missile Technology Control Regime (MTCR) regulations that prohibit the export of cruise missiles capable of carrying a 1,100lb payload more than 185 miles.
- CBU-105DB 1,000lb Wind Corrected Munitions Dispenser – which is a guided Cluster Bomb Unit.
- Dual mode 500lb and 2,000lb laser/GPS guided munitions.
- GBU-24 2,000lb Paveway III laser-guided bombs.
- GBU-31B (V3) 2,000lb Joint Direct Attack Munitions.
- GBU-39/B 250lb small-diameter bomb.
- Mk82 500lb and Mk84 2,000lb general purpose bombs.

The F-15SA uses two additional outboard underwing weapons stations (Stations 1 and 9) for increased weapons carriage.

The hardpoints were originally designed to accommodate pods for the Tactical Electronic Warfare Suite on the original F-15A. The intended equipment was abandoned when wind tunnel testing demonstrated the use of the two stations was longitudinally destabilising to the extent that the F-15's original flight control system couldn't cope. However, the digital fly-by-wire flight control system on the F-15SA is designed to allow use of outboard underwing stations 1 and 9.

Additionally, the digital fly-by-wire flight control system provides a significant reduction in maintenance compared to the original electro-mechanical system, which allows greater flexibility in tailoring control laws for specific flight conditions, loadings, and tasks.

Using experience gained from development of the F/A-18 and F-15 S/MTD control systems, as well as Boeing's unsuccessful X-32 Joint Strike Fighter contender, Boeing developed the digital fly-by-wire flight control system to make the F-15SA easier to fly than previous F-15 variants.

Production Standard Prototypes

The first three production standard F-15SAs were equipped with flight test instrumentation and were used as prototypes. All three jets undertook developmental flight testing of the digital flight control system and to recertificate the F-15SA throughout the Eagle's entire flight envelope – a major undertaking that took many months to complete.

The first aircraft, F-15SA 12-1001 (c/n SA-1) was ceremonially rolled out at Boeing's St Louis facility on April 30, 2013, in the presence of Lieutenant General Mohammed Bin Abdullah Al-Ayeesh, the then commander of the Royal Saudi Air Force, as well as senior Boeing and US Air Force leaders.

F-15SA 12-1002 (SA-2) made its maiden flight at St Louis on February 20, 2013 in the hands of Boeing test pilot Joe Felock, and weapon system operator Mark Snider. Aircraft 12-1001 (SA-1) followed on March 2.

Boeing expected the flight test programme to last for approximately 18 months, concluding in the summer of 2014.

Each of the three prototype aircraft was allocated specific flight test events: SA-1 for weapons testing, SA-2 for flutter and aerodynamics, and SA-3 for electronic attack and awareness.

F-15SAs SA-1 and SA-2 received high-visibility dayglo orange markings, very similar in design to those applied to the very first F-15As in the early 1970s, while the third aircraft retained its RSAF camouflage.

Beyond brief announcements of the rollout and of the first flight (the latter announcement actually happening three weeks after the event!), Boeing has always declined to make any comment on the F-15SA programme, but there have been reports of unspecified problems.

After the first week of April 2013, all flight testing was put on hold due to engineering issues with the digital fly-by-wire system. A stand-down was always planned for further control law development, system ground tests, and simulations, but some sources suggest that it occurred earlier, and went on for rather longer than expected, while envelope expansion with the

ABOVE: *A murky day at RAF Lakenheath, England as brand new F-15SA 12-1041 rolls-out after landing at the end of its transatlantic flight from Boeing's facility at St Louis. Most F-15SA aircraft staged through Lakenheath on their delivery to the Kingdom.* Simon Bullimore

new flight control system was slower than anticipated. Testing resumed in October, prior to the transfer of flight test activities to Palmdale on November 1, 2013. The move to Air Force Plant 42 at Palmdale was always planned, since higher risk activities, including flutter testing, stores separations, and flight at high angles of attack and with different stores configurations are best conducted in the vast test ranges managed by Edwards Air Force Base.

Change of Heart

It was initially thought that a US Air Force-led Royal Saudi Air Force training squadron would be based at Mountain Home Air Force Base in Idaho. It would consist of up to 18 F-15SA aircraft and associated personnel and come under the command of the 366th Fighter Wing. It was also anticipated that a Saudi training unit would remain at Mountain Home for at least a five-year period, operating alongside 42 US Air Force F-15E Strike Eagles and 14 Republic of Singapore Air Force F-15SGs.

Saudi operations were expected to result in a 32% increase in sorties using the Mountain Home Range Complex and associated airspace. The Saudis were to have paid for the construction, refurbishment, and modification of facilities, and provide equipment to operate the squadron and maintenance training function. In the event, the decision was taken that F-15SA training would be conducted in-kingdom, at King Khalid Air Base in Khamis Mushayt, after an initial cadre of aircrew were trained in the United States.

Mohawarean Aviation Services Company Ltd was selected by Boeing as its subcontractor for providing 'differences training' for the initial cadre of RSAF pilots, weapon system operators and maintainers moving over from other F-15 models, and for an initial cadre of US Air Force aircrew who would support the F-15SA programme.

Under the plan, up to six US Air Force and six RSAF crews were to have been trained in September and October 2014, prior to commencement of aircraft deliveries to King Khalid Air Base in Khamis in January 2015. Up to four additional instructor crews were then to have been trained in the January-March 2015 timeframe. Mohawarean Aviation Services employed 14 F-15SA instructor aircrew and 18 F-15SA academic and simulator instructors to begin the training task. This was almost certainly delayed as a result of delays to the flight test programme, since initial training was to have used early production F-15SAs, which were not flying at the time.

Today, the RSAF F-15S and F-15SA fleet is assigned to 92 Squadron/3 Wing at Dharan; 6 Squadron and 55 Squadron/5 Wing at Khamis Mushayt; and 29 Squadron/7 Wing at Tabuk.

Over the past decade the Royal Saudi Air Force has continued to train with allied air arms, not least during Exercise Red Flag at Nellis Air Force Base, Nevada, where it deployed F-15S aircraft in July 2010, February 2012 and February 2014, and F-15SA Eagles in March 2019.

BELOW: *This photo of an F-15S shows the conformal fuel tank configuration and the alignment of the stores hardpoints.* Paul Ridgway

F-15SG POISED & DEADLY

Mike Yeo reviews the F-15SG Advanced Eagle in service with the Republic of Singapore Air Force.

MAIN PICTURE: ***F-15SG serial number 8312 adorned with 149 Squadron tail markings. The aircraft is assigned to the squadron at Paya Lebar Air Base in the north of Singapore.*** *Nigel Pittaway*

The tip of the Republic of Singapore Air Force's spear is its fleet of Boeing F-15SG Eagle multirole fighters. Singapore selected the F-15 as the replacement for its fleet of modernised A-4SU and TA-4SU Super Skyhawks in 2005, signing a Direct Commercial Sales (DCS) contract with Boeing for an initial 12 aircraft and eight options after a lengthy and by all accounts, comprehensive evaluation process that pitted the Eagle against the likes of the Eurofighter Typhoon and Dassault Rafale.

Acquiring the jets under a DCS structure has allowed Singapore to customise its F-15s, which are based on the F-15E Strike Eagle, for its own requirements.

Customisation includes integration of a Raytheon APG-63(V)3 active electronically scanned array radar, along with provision for missile approach and warning system sensors in prominent housings on both sides of the aircraft just below the canopy and either side of the exhausts for the GE Aviation F110-GE-129C afterburning turbofan engines. Each F110-GE-129C engine is rated at 29,400lbf.

Singapore also acquired the Lockheed-Martin Sniper advanced targeting pod, Tiger Eye IRST (infrared search and track), Link 16 datalinks and Joint Helmet Mounted Cueing Systems for its F-15SGs. It has been rumoured that the type is also fitted with an Israeli electronic warfare and self-protection system, although this has not been confirmed.

Weapons include the AIM-9X Sidewinder and AIM-120 AMRAAM air-to-air missiles, the AGM154A Joint Stand-Off Weapon and the GBU-38/B JDAM.

The changes meant that Singapore's F-15SGs were the most advanced Eagles in service anywhere in the world until the F-15SA variant entered service with the Royal Saudi Air Force.

Maiden Flight

The F-15SG made its maiden flight at St Louis, on September 16, 2008 followed

RIGHT: ***Republic of Singapore Air Force pilots walk to their F-15SGs during a Cope Tiger exercise at RTAFB Korat.*** *US Air Force/Lt Jake Bailey*

by the official roll-out from Boeing's St Louis, Missouri facility in November 2008.

After making its first few flights from St Louis, the first F-15SG was flown to Air Force Plant 42 at Palmdale, California where it undertook the higher-risk flight test activities during 2009.

Flying from Palmdale the aircraft used the vast Edwards Air Force Base test range to conduct flutter testing, weapon separations, and flight at high angles of attack with different stores configurations.

Singapore's Continental United States F-15SG training detachment based at Mountain Home Air Force Base in Idaho received its first F-15SG in May 2009.

LEFT: ***An enormous tail marking denoting the Republic of Singapore's Air Combat Command indicating its global reach capability.*** *Nigel Pittaway*

Established as part of the foreign military sale programme called Peace Carvin V, the detachment comprises the joint US-Republic of Singapore Air Force 428th Fighter Squadron 'Buccaneers' and part of the resident 366th Fighter Wing.

The first pilots to graduate the course at Mountain Home provided the cadre required to transition 149 Squadron, based at Paya Lebar Air Base, Singapore, from the F-5S to the F-15SG. At a ceremony marking 149 Squadron's transition on April 5, 2010, deputy prime minister and Minister for Defence Teo Chee Hean said: "The F-15SG is a major enhancement to Singapore's air defence capability and will also play a significant role in the Singapore Armed Forces' overall operations."

Since 149 Squadron's transition, the 428th FS has conducted continuation training of F-15SG pilots and weapon system officers and more recently, the Republic of Singapore Air Force Advanced Fighter Weapons Instructor course.

By the time that the first aircraft arrived at Mountain Home, Singapore had already announced (in October 2007) it would take up the eight options and add a further four aircraft, for a total of 24 Eagles. The first F-15SGs arrived at Paya Lebar Air Base in northeastern Singapore during March 2010 and were assigned to 149 Squadron, a former Northrop F-5 Tiger II unit.

Singapore has never officially disclosed the number of F-15SGs in its inventory, citing operational security. However, known aircraft tail and/or construction numbers indicate that 40

BELOW: ***Republic of Singapore Air Force F-15SG 05-0007 assigned to the 428th Fighter Squadron based at Mountain Home Air Force Base, Idaho. It's seen here taxiing at Nellis Air Force Base, Nevada on March 18, 2021 prior to a mission during Red Flag 21-2.*** *US Air Force/William Lewis*

BOTTOM: ***Republic of Singapore Air Force ground crew check the stores loaded on F-15SG serial number 8323.*** *Nigel Pittaway*

RIGHT: ***Leaders of the Republic of Singapore Air Force, Air Combat Command's 366th Fighter Wing and local civic dignitaries at Mountain Home Air Force Base, Idaho on August 18, 2016. The leaders were there to attend the first-ever F-15SG Fighter Weapons Instructor Course graduation ceremony.*** *US Air Force/Airman 1st Class Chester Mientkiewicz*

BELOW: ***A Republic of Singapore Air Force pilot and a weapons system officer assigned to the US Air Force's 428th Fighter Squadron perform pre-flight checks on a F-15SG prior to a Red Flag training mission at Nellis Air Force Base, Nevada.*** *US Air Force/Lawrence Crespo*

aircraft were ordered in two separate and undisclosed batches after the initial 2007 order. Boeing delivered the final F-15SG aircraft in mid-2016.

Equipping with additional aircraft enabled the Republic of Singapore Air Force to stand up 142 Squadron at Paya Lebar in early 2016.

Overseas Training

Today, both squadrons continue to operate from the base although they frequently deploy overseas for training due to a severe shortage of military airspace over and around Singapore. Host nations include Australia, Guam and Thailand with which Singapore has signed agreements to use their military training areas.

In late 2020, the Republic of Singapore Air Force inaugurated an aggressor detachment resident with 140 Squadron, an F-16 unit based at Peya Lebar. When flying aggressor missions in support of F-15SG and F-16 squadrons, the detachment uses aircraft and crews from both the resident F-16 and F-15 squadrons as required.

The F-15SG made its maiden flight at Lambert Field, St Louis, on September 16, 2008 followed by the official roll-out in November 2008.

BELOW: ***Flagship F-15SG, serial number 05-2007, from the 428th Fighter Squadron based at Mountain Home Air Force Base, Idaho as part of the Peace Carvin V detachment lands at David-Monthan Air Force Base, Arizona during a training detachment.*** *US Air Force/ Senior Airman James Hensley*

America's NEW GUARDIAN

Mark Ayton describes the US Air Force's latest fighter jet, the F-15EX Eagle.

MAIN PICTURE: ***F-15EX 02-2001/ET at Eglin Air Force Base, Florida on March 11 following its delivery flight from Boeing's St Louis, Missouri facility.*** *US Air Force/Ilka Cole*

If your impression of the F-15 Eagle is one of a modern fighter aircraft, you might be surprised to know it's over 48 years old.

McDonnell Douglas test pilot Irv Burrows flew F-15 71-0280 on the type's maiden flight on July 27, 1972.

Built at the McDonnell Douglas facility adjacent St Louis-Lambert Field, the aircraft was unveiled there on June 26 and airlifted to Edwards Air Force Base in California in July. The aircraft was used for flight envelope, handling qualities and stores carriage testing by a combined McDonnell Douglas-US Air Force F-15 Joint Test Force until November 1975. Following an illustrious flight-test career, the aircraft was assigned to the Air Force Orientation Group based at Gentile Air Force Station, Ohio. Between 1979 and 1991, the aircraft was exhibited to the American public at shows and displays around the nation. Today, the aircraft is on display at the US Air Force History and Traditions Museum at Lackland Air Force Base, Texas.

Fast forward to the first quarter of 2021, St Louis-Lambert Field and the roll-out of the Boeing F-15EX; the latest variant of the two-seat F-15 Strike Eagle family, but single pilot operable.

Externally similar to the F-15E with the same outer mould line, internally the F-15EX is a transformation in terms of how its OFP software works, in terms of its sensor suite and its future upgradability. But the transformation also includes structural changes. Both the wing and the fuselage have been strengthened to improve fatigue-life, based on discoveries found during phase maintenance inspections.

An Advanced Eagle: F-15EX

According to Boeing's F-15 program manager, Prat Kumar: "The analysis undertaken on individual pieces of the structure that we've strengthened to enable the customer to get a longer useful life is very detailed and allows us to build new aircraft more efficiently. There have been hundreds of small changes on the inside of the airframe that make today's Eagle better.

One new enabling aspect of the Advanced Eagle is an open mission system architecture and processor. These allow rapid insertion of app-based software, which in turn enables insertion of, for example, new antennas, or the ability to conduct a new role like manned-unmanned teaming or functioning as a data node in the nascent Air Force Advanced Battle Management System dubbed ABMS.


US Air Force/Samuel King Jr

These examples are only made possible because of the aircraft's digital backbone and a fibre-optic data bus installed throughout the aircraft.

Weapon payload is another primary capability. The F-15EX will become the first aircraft in the Air Force inventory capable of carrying very large hypersonic stores measuring 20ft in length and weighing more than 7,000lb.

Boeing opted to not incorporate low observable design features on the Advanced Eagle primarily because it was not of interest to the Air Force. Commenting, Prat Kumar said: "What we offer with the F-15EX and its advance jamming capability is survivability against a broad range of frequencies. The aircraft is affordable because it doesn't require low-observable coating maintenance and offers a rapid means to adapt software. An advantage for adjusting its electronic warfare suite to counter new and emerging threats."

Both the front and the aft cockpit have undergone redesign as Prat explained: "As we learned about mission management, especially from the F-22 Raptor and F-35 Lightning II, we realised the amount of sensor and data fusion provided to the pilot was increasingly important. Our approach was to equip each cockpit with a large 19 x 11-inch high-definition display, rapidly adaptable, easily customised and synched to the head-up display.

"We also realised the importance of rapid weapon targeting and do so with a helmet-mounted sight. F-15EX has a digital helmet-mounted sight and a large area display in both the forward and the aft cockpits. A digital helmet-mounted sight attached to the top of the pilot and the weapons system officer's helmets interconnects with the aircraft and depending on which mode is selected, displays different information. It provides them with advanced targeting information and greater situational awareness."

Digital capability of the F-15EX comprises a variety of systems. Upfront is the APG-82 radar's active electronically scanned array (antenna) with the largest array face currently available on a fighter in the world. The larger the antenna, the smaller the detectable target at a greater range.

Located just aft of the radar is the mission computer known as the Advanced Display Core Processor II (ADCP II), which runs all of the avionics systems on the aircraft and manages all the data migrating around the aircraft. The processor has oodles of memory, and processing power that enables it to operate at 87 billion instructions per second, and sufficient input-output bandwidth to meet the F-15EX's future and projected sub-system demands. ADCP II also enables full exploitation of the APG-82 radar's capabilities such as tracking a large number of targets, operating mode simultaneity, and providing increased track data.

Right next to the mission computer is the Multifunctional Information Distribution System-Joint Tactical Radio System. Abbreviated to MIDS JTRS, it's a four-channel radio designed to run the complex Link 16 data link waveform, and up to three additional communication protocols, including the airborne networking waveform. The MIDS JTRS will connect the F-15EX with all of the other aircraft types equipped with the Link 16 system.

Located close by to the MIDS-JTRS is the electronic warfare system produced by BAE Systems, designated the ALQ-250 and called the Eagle Passive/Active Warning and Survivability System (EPAWSS).

APG-82 Radar

Raytheon's APG-82(V)1 active electronically-scanned array radar can simultaneously detect, identify, and track multiple air and surface targets at longer ranges than previous Eagle radars. Longer stand-off range facilitates persistent target observation and information sharing. Compared to its predecessor APG-63(V)3, the APG-81(V)1 provides:

- Near-simultaneous interleaving of selected air-to-air and air-to-ground functions.
- Enhanced air-to-air and air-to-ground classified combat identification capabilities.
- Longer range synthetic aperture radar (SAR) air-to-air target detection and enhanced track capabilities. Longer

ABOVE: *The most notable feature of F-15EX 02-2001 shown in this photo are the massive nozzles of the GE Aviation F110-GE-129 Enhanced Fighter Engines.* US Air Force/1st Lt Karissa Rodriguez

BELOW: *F-15EX 02-2001/ ET is marked with stylised tail markings for the 40th Flight Test Squadron's commander. Note the stores hard points on the conformal fuel tanks.* US Air Force/Ilka Cole

range and higher resolution air-to-ground radar mapping.

- Improved ground moving target track capability.

The APG 82(V)1 antenna and power supply are from the APG-63(V)3 radar model, and the radar receiver/exciter and CISP (common integrated sensor processor) are based on the APG-79 AESA system.

ALQ-250 EPAWSS

According to BAE Systems, the ALQ-250 all-digital system collects and processes electromagnetic energy to instantaneously capture a 360° aerial field of view to provide a comprehensive picture of the battlespace around the aircraft. This gives the pilot maximum situational awareness, helping to identify, monitor, analyse, and rapidly respond to potential threats. EPAWSS has a broad instantaneous bandwidth and high speed scanning capability to detect all radio frequency (RF) threat classes including low probability of intercept and modern agile threats. To counter threats, the ALQ-250 electronic countermeasure technique toolbox can be programmed to defeat legacy and modern threats.

BAE Systems lists the following features and benefits:

- Offensive and defensive digital electronic warfare capabilities.
- Modular, scalable, open-system architecture.
- All-aspect, broadband radar warning and geolocation.
- Multi-spectral, radio frequency (RF) and infrared (IR) countermeasures.
- Simultaneous jamming without interfering with radar and radar warning receiver.
- Interoperable with active electronically scanned array radar.
- Integrates radar warning and countermeasures into one system.
- Increased situational awareness.
- Reduces F-15 electronic warfare footprint.
- 50% more chaff and flares than aircraft today.

EPAWSS is designed to provide indication, type, and position of ground-based RF threats as well as bearing of airborne threats with the situational awareness needed by the pilot to avoid, engage or shoot down the threat. It also defends against RF and infrared threat systems detecting or acquiring accurate targeting information prior to engagement thus complicating and/or negating an enemy threat targeting solution. The system counters threats through its suite of components using electro-optical and RF techniques.

Prat said the ALQ-250 detects signals throughout the 360° sphere around the aircraft, across a very large frequency band, and determines the best technique to send a jamming signal back against the threat.

During a ceremony held at Eglin on April 7, the US Air Force unveiled the name of its newest fighter as the F-15EX Eagle II

> **"The combined capability of the APG-82(V)1 radar and the ALQ-250 EPAWSS electronic warfare suite make the F-15EX extremely survivable in today's battlespace."**
> Matt Giese, Boeing F-15 chief test pilot

Legion Pod

One of the F-15EX's primary sensors is an infrared search and track (IRST) system housed in a pod carried on the under fuselage centreline station. An IRST provides a passive means to detect and track objects from infrared radiation by scanning a large volume of airspace ahead of the aircraft. This capability complements the radar to enhance the aircraft's survivability and lethality against air-to-air threats and provides the aircraft mission computer track file data on infrared targets.

Infrared energy can be generated by aircraft systems or by the friction produced by the aircraft's skin as it flies through the air. Any such detection enables the pilot to slave the radar onto the emissions for lock-on, or by geolocation calculated by the high-speed processor using interferometry.

A centreline pod carried on the under fuselage centreline station is depicted in Boeing's F-15EX artist renderings. That pod looks like Lockheed Martin's modular sensor system dubbed the Legion pod. According to Lockheed Martin, the Legion Pod is a multi-function sensor system that supports collaborative targeting operations in radar-denied environments. Housed in a 16-inch diameter fuselage, Legion Pod's baseline configuration includes an IRST21 sensor and advanced processor for high-fidelity detection and tracking of air-to-air targets.

Legion Pod has completed flight tests and integration on F-16, F-15C and F-15E aircraft, successfully demonstrating its detection and tracking capabilities in representative threat environments. Equipped with a common interface, it's easily integrated onto any aircraft without affecting that aircraft's operational flight programme software. Due to its open architecture, the system can accommodate and operate multiple sensors simultaneously, depending on the operator's requirements.

A Pilot's Perspective

Matt Giese is Boeing's F-15 chief test pilot. He works for a department called Boeing Test and Evaluation, which has end-to-end involvement from the beginning of system design until the final flight test and delivery of the aircraft to the government customer.

Matt served in the active-duty US Air Force and flew F-16, F-15, and F-22, and continues to serve as a reservist in a non-flying role. He has much experience flying Advanced Eagles such as the Saudi F-15SA and the Qatari F-15QA. Discussing the nascent F-15EX, Matt said it has three major pillars: digital fly-by-wire flight control systems, GE Aviation F110-GE-129 engines, and its mission systems, including sensors and an electronic warfare system.

Matt explained the benefits that F-15EX pilots will gain from the aircraft's four-channel, quad-redundant, digital fly-by-wire flight control system. He said: "It allows the pilot to focus more on the mission event because the digital fly-by-wire system design provides stability, efficiency, predictability, reliability and a very high level of performance. Not just at Mach 2.5 and high altitude but more importantly at slow speeds and a high angle-of-attack.

"The Advanced Eagle has been tested and vetted throughout the entire flight envelope - low and slow, high and fast, out to Mach 2.5, high angles-of-attack -

LEFT: ***Lieutenant Colonel Richard Turner, Commander, 40th Flight Test Squadron, and Lieutenant Colonel Jacob Lindaman, Commander, 85th Test and Evaluation Squadron cruising en-route from St Louis to Eglin Air Force Base, Florida on March 11.*** *US Air Force/TSgt John McRell*

RIGHT: ***F-15EX 02-2002/ OT painted with stylised tail markings for the 53rd Wing's commander during its first mission from Eglin on April 26, 2021.*** *US Air Force/1st Lt Savanah Bray*

such that the aircrew can fly the aircraft with ease, in the knowledge that its flight control system will protect them and the aircraft alike, allowing them to focus on the mission tasks. Around 15,000 test points were performed.

"Advanced Eagle has two flight control computers with two branches, each branch controls the fly-by-wire system. To aid the pilot, a help page is always displayed in the cockpit showing inputs to the flight control system and the outputs to each individual control surface. Even at a glance, the pilot can determine the health of the system; green is good, yellow indicates redundancy is being lost, and red shows it's starting to fail."

Power on Tap

Given the F-15EX will have plenty of power to operate, generated by two GE Aviation F110-GE-129 turbofan engines each rated at 29,000lb, it should have no problem conducting the roles currently performed by the F-15C. Neither should it struggle to fly high and fast and give energy and kinematics to its air-to-air missiles. Matt said the F-15EX is on par with the F-22 in many aspects of manoeuvrability thanks to the GE engines and its digital fly-by-wire controls.

The F110-GE-129 EFE is a two-spool, low-bypass, axial-flow turbofan engine with afterburner. Its main components forward to aft are a front frame, a three-stage long chord blisk fan (driven by the two-stage low-pressure turbine), a fan frame, a nine-stage high-pressure compressor (driven by the single stage high-pressure turbine), a combustion diffuser nozzle, a turbine section (high-pressure turbine, low-pressure turbine), a turbine frame, an augmenter mixer, an advanced close-coupled radial augmenter, an exhaust, and a convergent-divergent type nozzle.

The engine is equipped with a digital engine control unit which controls fuel flows, rotor speeds, variable geometry, pressures, and temperatures in the engine.

An F110-GE-129 engine measures 182 inches in length, has a 46.5-inch max diameter, and weighs 4,010lb.

GE Aviation developed the F110-GE-129 EFE (Enhanced Fighter Engine) using the following low risk technologies:

- A three-stage long chord blisk fan for greater efficiency, an increased inlet airflow rated at 275lb/sec, and a reduced parts count. This feature was adapted from the B-2 Spirit's F118-GE-100 engine.
- An advanced radial augmenter derived from concepts used in the F120 (Lockheed YF-22 and Northrop YF-23) and F414 (Boeing F/A-18 Super Hornet) engines that reduces complexity, improves maintainability and reliability, and improves parts life by over 50% due to advanced cooling of the augmenter parts.
- A lightweight filament-wound composite fan duct.
- Control system enhancements that manage the engine's power up to 34,000lb of thrust.

GE Aviation delivered two F110-GE-129 engines to Boeing for installation in the first F-15EX in September 2020. It remains the only type of engine certified for the fly-by-wire F-15EX. In 2014, GE Aviation made a long-term commitment with the investment required to qualify the F110-GE-129 engine on variants of the Advanced Eagle including the F-15EX.

In May, both F-15EX Eagle II fighters flew in Exercise Northern Edge 2021

Mission Systems

According to Matt, the F-15EX's two primary mission systems are the APG-82(V)1 radar and the ALQ-250 EPAWSS electronic warfare suite. "Their combined capability make the F-15EX extremely survivable in today's battlespace."

Having flown the F-22 for 12-years, Matt believes there are multiple ways to achieve the same or similar battlespace affects with the F-15EX.

Discussing this aspect, he said: "Equipped with the most powerful large array radar antenna in the world gives the F-15 far superior performance in some mission elements. Add in the effect of EPAWSS with its offensive and defensive capabilities, and manage the two systems together, and in many cases, it results in a greater, more supportive and complimentary battle space effect than you would get with a stealth fighter."

Matt was asked if the battlespace picture presented on the large area display is fused together from data fed from the sensors, and whether that picture gives the pilot surety that if going into harm's way, he or she would know where all the threats are located?

Unsurprisingly, Matt would not discuss details of sensor fusion on the F-15EX. However, he said the large area high-resolution display provides a very large battlespace picture, one that shows inputs from all of the aircraft's sensors. Matt said: "The situational awareness afforded to an F-15EX aircrew will be far beyond that presented in the cockpit of an F-15C or an F-15E, and on par or exceed the fidelity of F-22 and F-35 displays. Threats are identified clearly and quickly, which certainly increases the pilot's situational awareness. That's all possible because of the ADCP II mission computer which filters out the most important information to avoid overloading the pilot with cues and targets around the battlespace."

Measuring 19 x 11 inches, the F-15EX cockpit large area display designed and produced by Israeli company Elbit Systems, is the basis of Boeing's Advanced Crew Station (ACS). The display integrates tactical data, mission planning and flight information into a complete situational picture and responds to specific mission phases and pilot controls. Boeing's primary objectives for designing the ACS were to improve the pilot's interaction with the aircraft and operate in synch with the digital helmet-mounted cueing system. These aspects improve the pilot's situational awareness and increase mission effectiveness."

For an aircraft of its size, the F-15EX will be able to carry an unprecedented weapon payload thanks in part to the fly-by-wire design and if the Air Force chooses to integrate the new Advanced Missile Bomb Ejector Rack dubbed AMBER. Previously unpopulated stations 1 and 9 can now carry air-to-air missiles, increasing the F-15's missile loadout to 12, which increases to 22 when the AMBER rack is used. Boeing developed the AMBER rack as part of a research and development programme as a means to carry additional air-to-air missiles or other munitions.

Commenting on that possibility from a mission systems standpoint, Matt said the combination of digital design, integrated mission systems, and a potential missile loadout of 22, makes the F-15EX a highly lethal platform.

EX Deliveries and Production Lots

In mid-July 2020, the Air Force awarded Boeing a contract valued at nearly $1.2bn for the first low-rate initial production lot of eight F-15EX aircraft.

Under the terms of the contract, Boeing will provide for the design, development, integration, manufacturing, test, verification, certification, delivery, sustainment, and modification of the F-15EX aircraft, including spares, support equipment, training materials, technical data, and technical support.

Under current plans, the Air Force intends to procure 76 F-15EX aircraft over the five-year Future Years Defense Program; the eight in Lot 1 were approved in the FY2020 budget and 12 were requested and approved in FY2021. F-15EX aircraft built in Lot 2 and Lot 3 will equip the Oregon Air National Guard's 173rd Fighter Wing based at Kingsley Field from FY2024, followed in FY2025 by the first aircraft for the 142nd Wing at Portland Air National Guard Base – the first F-15EX operational unit.

ABOVE: *Loaded for its flight from northern Florida to Alaska for participation in Exercise Northern Edge 2021, F-15EX 02-2002/OT fitted with crew baggage pods, AIM-120 AMRAAM and AIM-9 Sidewinder missiles.* US Air Force/1st Lt Savanah Bray

ABOVE: ***F-15EX 02-2002/OT over Florida's Emerald Coast near to Eglin Air Force Base.*** *US Air Force/1st Lt Savanah Bray*

For the Air Force, the F-15EX represents more than new iron on the ramp. As a major design series type, it will require minimal transitional training or additional manpower and little to no infrastructure changes at the bases selected to host the type.

According to General Holmes, the then commander of Air Combat Command: "The F-15EX will be ready to fight as soon as it comes off the line. When delivered, we expect bases currently operating the F-15 to transition to the new EX platform in a matter of months versus years."

The first of eight F-15EX aircraft to be assigned to Eglin Air Force Base, Florida, serial number 20-2001/ET (c/n EX-1) was flown to Eglin on March 11 by the commanders of Air Force Materiel Command's 40th Flight Test Squadron (developmental test) and Air Combat Command's 85th Test and Evaluation Squadron (operational test). The Air Force had accepted the jet the previous day at Boeing's St Louis, Missouri facility.

The second aircraft, 20-0002/OT (c/n EX-2), was flown to Eglin by General Mark Kelly, commander Air Combat Command on April 20.

EX-1 is assigned to the 40th Flight Test Squadron, while EX-2 is assigned to the 85th Test and Evaluation Squadron. Both aircraft will be used to support the integrated test and evaluation team (ITET) placing the F-15EX as the first Air Force aircraft to be completely tested and fielded through combined developmental and operational test. Assigning the jets at Eglin will allow the co-located test squadrons to share the aircraft and work in parallel, but independently of each other, to accomplish both test efforts in the least amount of time and cost.

Test data from the extensive flight test programme undertaken by Air Force Materiel Command for the Saudi F-15SA is being used to support the F-15EX, though specific US avionics and software will be tested by the ITET at Eglin and other locations. Digital engineering models used for the F-15SA were used for the F-15EX nose barrel and wings, in addition, the US Air Force funded the digital engineering of the jet's fuselage. F-15EX systems currently under test include the mission computer, fly-by-wire systems, and the ASQ-250 Eagle Passive Active Warning Survivability System.

Commenting on the F-15EX, the Air Force Life Cycle Management Center at Wright-Patterson Air Force Base, Ohio said in a press release: "The F-15EX provides a cost-effective and expedient solution to refresh [replace] the F-15C and F-15D fleet and augment the F-15E fleet. This will meet National Defense Strategy capability and capacity requirements well into the 2040s, while avoiding aircraft availability disruptions that would result from a service life extension or modification programme."

During a ceremony held at Eglin on April 7, the Air Force unveiled the name of its newest fighter jet as the F-15EX Eagle II. Speaking at the ceremony, Lieutenant General Duke Richardson, the military deputy in the Office of the Assistant Secretary of the Air Force for Acquisition, Technology, and Logistics, said: "Quick adoption of the F-15EX is needed because of the state of the current F-15C and F-15D fleet. Ten percent of the fleet is grounded due to structural issues, with 75% flying beyond their certified service life. The fleet has an average age of 37 years, and a life extension is cost prohibitive."

Both F-15EX Eagle II fighters flew in the Pacific Air Forces Exercise Northern Edge 2021 operating from Elmendorf Air Force Base. Northern Edge is the largest and most robust exercise staged by the United States, involving a variety of weapon system experiments and consequently US units only. The two Eglin-based F-15EX aircraft participated in broader Joint All-Domain Command and Control (JADC2) experiments and tested the jet's new ASQ-250 Eagle Passive Active Warning Survivability System electronic warfare suite. According to Lieutenant General David Krumm, commander of the Alaska-based 11th Air Force: "The exercise included every aspect of JADC2. Experimental systems included SpaceX Starlink satellites, new remote satellite terminals from the Air Force's Rapid Capabilities Office—which manages the Advanced Battle Management System—as well as different technologies in the electromagnetic spectrum, jamming with radars, ... [and] a whole array of new experiments." Northern Edge 2021 was staged between May 3-14.

The GOLD TEAM

Mark Ayton reports on the latest operations flown by the F-15C-equipped 493rd Fighter Squadron.

MAIN PICTURE: ***F-15C Eagles assigned to the 493rd Fighter Squadron fly back to RAF Lakenheath on March 19 after completion of exercise Baltic Trident at Ämari Air Base, Estonia.*** *US Air Force/Airman 1st Class Jessi Monte*

Based at RAF Lakenheath since January 1960, the current 493rd Fighter Squadron has flown the F-15C Eagle for 28 years, which makes it the squadron's longest-assigned aircraft. The former F-111F squadron was inactivated on December 18, 1992 and re-activated as an F-15C squadron on January 1, 1994. Today the 493rd is a super busy unit conducting temporary duty deployments around the US Air Forces in Europe theatre, a high operational tempo of flight operations at Lakenheath in addition to its historic participation in Operations Southern Watch, Iraqi Freedom, Enduring Freedom, Odyssey Dawn and since 2000, Air Expeditionary Force commitments in southwest Asia.

With 400 airmen and over 20 F-15s assigned, the 493rd Fighter Squadron has racked up some notable events in 2021 to date. The author spoke with the squadron's commander, Lieutenant Colonel Mark Perry about recent accomplishments.

Missiles, the Baltic, and Bombers

In early March, the squadron conducted a series of live firings involving AIM-9 Sidewinder and AIM-120 AMRAAM air-to-air missiles. The COVID-19 pandemic hampered the squadron's opportunity to deploy to Tyndall Air Force Base, Florida to attend Air Combat Command's Combat Archer Weapon System Evaluation Program. The programme provides aircrew with the opportunity to employ air-to-air missiles.

Explaining the missile firings, Lt Col Perry said the squadron came up with creative solutions that enabled some of its young pilots who were first time shooters to conduct a WSEP evaluation in the UK. "It was a huge accomplishment involving coordination with the Royal Air Force, the Ministry of Defence and the folks at Tyndall that run Combat Archer who ensured our instructors were qualified to be supervisors. We shot AIM-120s over the Atlantic Ocean within the Hebrides Range Complex and AIM-9s over the coast of Wales at the Aberporth range. Every time we pressed the pickle button, everything worked the way it should such that we were 100%

successful. And from the maintenance and munitions team perspective, the young airmen safely loaded older live AIM-120B missiles on the jets without a hitch which is a big accomplishment."

A couple of weeks later, the 493rd Fighter Squadron deployed four F-15Cs to Amari Air Base, Estonia, for Baltic Trident, an Agile Combat Employment exercise designed to increase interoperability among NATO allies and partner nations. For the 493rd, Baltic Trident tested its ability to effectively execute missions at a forward operating location with varying levels of support and a smaller manpower footprint. The Agile Combat Employment concept of operations is designed to minimise the reliance on prepared airfields by enabling the dispersal of smaller units to various locations and still meet operational needs.

Between March 15 and 19, a skeleton team of fewer than 40 48th Fighter Wing airmen and aircrew supported and flew four F-15Cs and four F-15E Strike Eagles, a tasking typically supported by over 100 personnel. F-15C pilots flew dissimilar air combat training missions with the Finnish, German, and Polish Air Forces. Commenting on the 493rd's success, Lt Col Perry said: "It was great work done by first assignment, four-ship flight leads with brand new wingmen to get the mission done."

The 493rd also participated in another Baltic-centric exercise to practise new techniques and procedures required to find and strike high value targets in accordance with the Joint All-Domain Command and Control or JADC2 concept of connectivity. Explaining, Lt Col Perry said the 48th Fighter Wing employed F-15Cs and F-15Es in combination with ally aircraft in what is referred to as a find, fix, track and target exercise. The exercise comprised a joint targeting scenario and the simulated employment of long range munitions over the Baltic and involved US and UK ISR aircraft. Its objective was to evaluate the entire kill chain that would be required in a possible future operation.

Back home at Lakenheath, all three of the resident flying squadrons participate in regular large force employment exercises which typically involve operations with Royal Air Force and Royal Netherlands Air Force fighter squadrons.

RAF Lakenheath is an ideal location for this type of training, primarily because of its close proximity to air space in the North Sea ranges and the ability to train with other fighter squadrons, which now includes Dutch and UK F-35s.

During the recent work-up for its

ABOVE: ***F-15C Eagle 86-0160/LN with an empty missile rail after a live missile firing over the Atlantic Ocean.*** *US Air Force/SSgt Rachel Maxwell*

BELOW: ***F-15C Eagle 86-0160/LN loaded with a live AIM-120B missile at RAF Lakenheath, England on March 3, 2021.*** *US Air Force/SSgt Rachel Maxwell*

ABOVE: **F-15C Eagle 86-0160/LN receives fuel from a KC-135R Stratotanker assigned to the 100th Air Refueling Wing based at RAF Mildenhall, England. The refuelling was taking place prior to a live missile fire exercise over the Atlantic Ocean on March 3, 2021.** *US Air Force/SSgt Rachel Maxwell*

inaugural cruise on HMS *Queen Elizabeth*, 617 Squadron, the UK's sole front line F-35B unit undertook a lot of air-to-air training with the 493rd Fighter Squadron. Scenarios flown between F-15C Eagles and stealthy F-35B Lightning IIs is mutually beneficial to the pilots assigned to both squadrons. It presents the Eagle pilots with opportunities to fight the so-called fifth-generation jet, and the UK Lightning pilots to take on F-15s.

But life on the 493rd goes beyond duels played out with other steely nosed fighter jets. Supporting US Air Force strategic bombers flying Bomber Task Force deployments is also a regular calling. When tasked with supporting a Bomber Task Force mission, the 493rd typically undertakes the offensive counter air role; one of the squadron's primary mission sets which involves escorting the bombers.

According to Lt Col Perry: "Bomber Task Force missions that involve integrated training provide an opportunity to train in offensive counter air. Defending a B-1 or defending a B-52 is a very different problem set to defending an F-15E which carries its own missiles and can defend itself. One thing that's especially different with Bomber Task Force missions is that they typically come from a base in the continental United States. They are typically geographically separated from us which means that all aspects of the mission present a unique, but highly applicable, problem that we would face in any kind of real world scenario. The length of the sortie being flown by the bombers and the time difference with their station of departure are a couple of challenges presented.

"Historically, bombers have typically conducted combat operations from bases in the continental United States by flying extremely long sorties to arrive on station and then integrate with a strike package originating from other locations. For our young pilots, it's a unique opportunity to practice mission planning with geographically separated units and fly the mission in the most challenging scenario."

Gold Surge

The 48th Fighter Wing generates a lot of sorties on any flying day at Lakenheath. That single aspect is the result of 400 airmen who work as maintainers, crew chiefs, ammo troops, life support technicians, refuelling troops, the list goes on because there are many of them. It is an enormous, multifaceted, well-oiled machine that functions every flying day to generate aircraft for the day's flight schedule.

Commenting on the 493rd FS, dubbed 'The Gold Team', Lt Col Perry said: "We have a saying, it's good to be gold. That goes for everyone in the fighter squadron, our 493rd Aircraft Maintenance Unit, life support, intel support, our ICOs who check our training and currencies, everyone, they are an awesome team. The proof is in the pudding. During the recent Gold Surge exercise, over the course of four days we flew 216 out of 216 planned sorties. Typically, the squadron generates 230 to 250 sorties a month. That's 54 sorties a day for four days straight. Maintenance achieved 100% delivery of primary and spare aircraft. On about 200 of those sorties, the aircraft returned to base in code 1 condition. It was the highest sortie count and the most successful surge the wing has had in over five years."

Exercises such as the recent Gold Surge are staged to evaluate and

RIGHT: **A crew chief assigned to the 748th Aircraft Maintenance Squadron marshals an F-15C Eagle onto the apron for hot-pit refuelling during surge operations at RAF Lakenheath on March 25, 2021.** *US Air Force/Airman 1st Class Jessi Monte*

demonstrate that a single squadron, sometimes an entire wing, can generate a pre-determined number of sorties and sustain that rate for a given period of time. But there are other important reasons for staging a sortie surge such as individual pilot's currency and training. During Gold Surge, some of the 493rd's youngest pilots flew 12 times.

Lt Col Perry explained the benefits: "There's not a whole lot of training that substitutes for just rapid repetition. The level of comfort that you get in the aircraft taking off multiple times a day, in the seat for hours a day. It's hard to replace the currency and the level of expertise that you gain from that kind of experience."

As part of the surge, the 493rd conducted hot-pit refuelling, the process in which ground crew refuel an aircraft while its engines are still running. The process allows the aircraft to get airborne again as quickly as possible, eliminates the need for extra maintenance and extends pilot training time for each flight.

One less typical event undertaken during the recent surge was dissimilar air combat training between 493rd FS F-15s and UK F-35Bs based at nearby RAF Marham. The UK jets landed at Lakenheath where the pilots undertook a debrief and then a brief for the follow-on sortie in a COVID-safe manner. The two units culminated the week with a joint training event.

Maintenance

It is an inescapable fact that maintaining a squadron of high-performance F-15s which are 35 years old requires a lot of effort from the airmen assigned to the 493rd Aircraft Maintenance Unit. A fact not lost by Lt Col Perry: "What they do with 35-year-old aircraft is incredible. We're launching more sorties using aircraft with a higher quality maintenance state than I remember. To do it through Covid especially when they can't go anywhere, it's a challenging circumstance to say the least. To pull off a surge let alone in Covid, it's incredible.

According to Lt Col Perry, working within the restrictions is a substantial factor. "But at the end of the day we've got to maintain readiness. We're pushing through it in accordance with not only US and CDC guidelines, but UK guidelines. It's a different way of doing business every day. All base agencies are operating and pushing through COVID as well, coming together to support surge operations and extended flying windows.

"Airmen assigned to the 48th Logistics Readiness Squadron make sure fuel trucks are in position so that we get the gas we need and there have been no delays getting into the hot pits. Our intel professionals continue to make sure the pilots are all prepared and ready for each and every type of mission. They check our currencies at the desk before we step to go fly a mission. Life support takes care of all helmets, G-suits, and exposure suits, which we have to wear for missions flown over the local cold waters of the North Sea and elsewhere. They maintain all of that stuff and do it in a COVID-safe manner because they're touching personal equipment."

ABOVE: ***An airman assigned to the 748th Aircraft Maintenance Squadron conducts hot-pit refuelling of an F-15C Eagle during surge operations.*** *US Air Force/ Airman 1st Class Jessi Monte*

ABOVE: ***A fuels distribution technician pushes a mobile pantograph away from an F-15C Eagle after hot-pit refuelling.*** *US Air Force/Airman 1st Class Jessi Monte*

LEFT: ***F-15C Eagles assigned to the 493rd Fighter Squadron line the arming pad prior to take-offs during surge operations at Lakenheath.*** *US Air Force/Airman 1st Class Jessi Monte*

ABOVE: ***An F-15C Eagle assigned to the 493rd Fighter Squadron sits static inside a protective aircraft shelter prior to a mission during surge operations at Lakenheath on March 25, 2021.*** *US Air Force/Airman 1st Class Jessi Monte*

BELOW: *Credit: US Air Force/Airman 1st Class Jessi Monte*

Adapting to Agile Combat Employment

The author asked Lt Col Perry how airmen assigned to the 493rd FS have dealt with the impacts of the COVID-19 pandemic and the Agile Combat Employment concept? "It's funny because COVID has forced our hand in a couple of ways. We've had to find ways to be more efficient with the resources we have, and work through the impacts that COVID inevitably has. We aren't immune from the effects of COVID. If one of our maintainers gets it or is exposed to someone with it off base, through contact tracing the squadron can very quickly lose several airmen to quarantine," he replied.

"Under the Air Force concept called multi-capable airmen, we send personnel to an Agile Combat Employment academy where they learn new skills. That could be a maintainer who has one speciality and learns the basics of other trades, or even a pilot. In January, we had pilots out on the ramp doing what's called B-man or backup to the crew chief duty. We were following the instructions of the crew chiefs catching fuel, pulling chocks, and putting chocks in. It's good for us to get hands-on appreciation for what our maintainers do on a day-to-day basis."

Current and Future Role

Lakenheath's 48th Fighter Wing provides combat air power to US combatant commanders. Air power comes in many different forms. At Lakenheath that can involve missions flown by F-15Cs and F-15Es. As the sole air superiority squadron in the 48th Fighter Wing and US Air Force in Europe, the 493rd Fighter Squadron's objective is to take the air superiority burden off the rest of a joint or coalition force so that other aircrews can be effective in their specific mission set, and not be distracted or restricted by the threat of enemy aircraft. According to Lt Col Perry the Air Force is most effective when specific capabilities and the strengths of each type of aircraft is utilised to its full potential.

In the case of the F-15C Eagle its full potential is highly capable. While the airframe is old, it is equipped with the latest radar, sensor, and weapon upgrades. Lt Col Perry said: "The airframe is solid. If anything speaks to the soundness of the F-15's design, just look at the F-15EX Eagle II which the Air Force is now buying nearly 50 years since the type's first flight. The Eagle is an amazing aircraft that is still operating in large force training exercises and getting the job done."

Yet the F-15 aircraft is entering the end of its service life. In the history of the 493rd, it's the 12th aircraft operated by the squadron; its next likely to be the F-35A. Lt Col Perry concluded: "We'll see what happens, but the F-35A represents the future of the US Air Force and the 48th Fighter Wing."

"Over the course of four days we flew 216 out of 216 planned sorties."

Lieutenant Colonel Mark Perry, 493rd FS

LANCERS

Mark Ayton reports on the F-15E training course managed by the 333rd Fighter Squadron based at Seymour Johnson Air Force Base, North Carolina.

MAIN PICTURE: ***F-15E Strike Eagles of the 4th Fighter Wing perform an Elephant Walk down the Seymour Johnson Air Force Base runway.*** *US Air Force/SSgt Elizabeth Rissmiller*

Since its activation in December 1957 as the 333rd Fighter-Day Squadron, the unit has operated four types of aircraft prior to the F-15E Strike Eagle: The F-100 Super Sabre, F-105 Thunderchief, the A-7 Corsair II and the A-10 Thunderbolt.

Today, the squadron's assigned staff comprises nearly 100 officers and over 300 active duty airmen who hold 15 different Air Force Speciality Codes. It is organised as a Total Force Integration unit with two Air Force Reserve components: instructor pilots assigned to the associate 307th Fighter Squadron are resident in, and fly with the 333rd, and there's a reserve maintenance component from the 414th Fighter Group.

Its commander is Lieutenant Colonel Jonathan Bott. The author spoke to the squadron boss about its role as a Flying Training Unit (FTU) and the courses it runs to train F-15E pilots and weapon systems officers (WSOs), either those that are brand new to the aircraft or those who are transitioning back to the Strike Eagle after a time away. The latter includes senior-ranked officers promoted to leadership positions within F-15E-equipped units.

After completing undergraduate pilot or combat systems officer training and a two-month introduction of fighter fundamentals course to learn the basics of flying fast jets, brand new officers arriving at the 333rd spend approximately ten months on the B-course learning to fly and operate the Strike Eagle.

Lt Col Bott, an experienced F-15E WSO encapsulated the new recruits: "they come to us with a lot of Mach and not a lot of vector."

Other than specific daily briefings, pilots and WSOs are paired together at the start of the training and work as a crew throughout the course. From the start, this approach builds the synergistic relationship required for the two-person F-15E crew under the adage that one plus one equals something much greater than two. The two crew must learn what the other one is attempting to do and build upon that without having to do the other one's job. According to Lt Col Bott "that's foundational to what we do."

Course Outline

The first 40 days are spent in classrooms and operating device trainers under former Strike Eagle instructors working for contractors. They teach the basic aspects of the aircraft and provide insight as to what to expect when the crews first start to operate the jet. This includes sessions in an integrated avionics trainer (which looks like a mock cockpit) in which they work through basic missions, learning how to work the aircraft's avionics and systems.

This is followed by sessions in a 360° (but not full motion) simulator in which crews conduct basic missions before their first flight. Crew transition to the aircraft, typically around the midway point of the course, but before they 'go to the flight line' they use VR technology to complete virtual walk arounds of a jet for familiarity, most notably on the day or evening before they are due to fly for the first time. The US Air Force introduced VR systems within the past 24 months.

Based on data analysis conducted during the past year, the 4th Fighter Wing has determined that the proximity of simulator sessions to flights gives better outcomes to training events, but equally it showed no statistical significance between the proximity of academic sessions to flights. That said, the wing continues to schedule crews through as much academic study as is possible before their first flight.

Once a crew 'goes to the flight line', they fly a set number of sorties as part of their transition from ground-based training to flying, five sorties for a WSO and six for a pilot. Interestingly, transition is the only phase of the course that comprises a different number of flights for the pilot and WSO. The pilot's sixth flight is an instrument check. If passed, the pilot is then cleared to be the aircraft commander without the need for another pilot onboard. All transition phase flights are flown with an instructor pilot and introduce the students to the basic aspects of the aircraft systems, instruments, and formation flying.

All Strike Eagles have controls in both the front and aft cockpits, so almost everything can be input and commanded from either cockpit, including take-off and landing if required.

That said there are some limitations. The officer in the front seat has the only handle with which to lower the landing gear, but in an emergency the officer in

ABOVE: ***An F-15E Strike Eagle assigned to the 333rd Fighter Squadron approaches the boom of a KC-135 Stratotanker from Ohio Air National Guard's 121st Air Refueling Wing.*** *Ohio Air National Guard/ Airman 1st Class Tiffany Emery*

RIGHT: **An F-15E uploads fuel from a KC-135 Stratotanker. Note the offset position of the refuelling receptacle on the aircraft's left side.** Ohio Air National Guard/ Airman 1st Class Tiffany Emery

the aft seat can 'blow down' the landing gear.

The officer in the aft seat has limited straight ahead visibility which means they have to use peripheral vision during landing. All instructor pilots are qualified to do so. Nor can the officer in the aft seat fire the M61 Vulcan cannon for the same reason.

The aircraft being able to be flown from either cockpit has its benefits in the training context as Lt Col Bott explained: "If I'm in the backseat flying with a young pilot and he's unable to understand the mechanics of what I'm asking him to do, either a previously briefed event or he's making a mistake, he can shadow the controls as I walk him through the mechanics of the manoeuvre being attempting. We see some good outcomes thanks to this capability."

There are six further phases to the course staged in the following order. Each phase is explained by Lt Col Bott.

Basic Fighter Manoeuvres

"The next phase starts off with offensive basic fighter manoeuvres [three sorties] where we park a bandit in front of them and they learn how to employ air-to-air missiles and use HOTAS to get manoeuvrability out of the jet at both high and low speeds. They transition to defensive BFM [three sorties] where we park the bandit behind them and they start to use the defensive systems on the jet, working together as a crew in order to manoeuvre the jet and survive, or ideally to turn the tables on the bandit.

BELOW: **An F-15E pilot signals the boom operator of a KC-135 Stratotanker after completing aerial refuelling.** Ohio Air National Guard/Airman 1st Class Tiffany Emery

"We complete a further two sorties designed to train them to use the vertical element, think in three dimensions and gain a real understanding of the energy that is on their jet and how to use it as a weapon. The goal here, which is often misconstrued, is for them to understand the manoeuvrability of the aircraft and to be able to apply it in any scenario that they're going to face later on. Time spent in a part-task trainer helps a crew to learn how to work together, use tactical crew coordination, and use all of the avionic systems on the aircraft in order to employ it in more of a tactical scenario."

Basic Air Combat Manoeuvring

Air combat manoeuvring (ACM) is split into two phases, basic and advanced. Basic ACM teaches them how to operate as a formation - the basic fighting element for the F-15. One sortie, sometimes two, is flown involving two blue air versus one red air, all within the visual range. The term blue air is used for the friendly F-15Es while red air is used for enemy aircraft. Red air aircraft are more often than not contractor operated A-4 Skyhawks, sometimes Air Force F-16s or navy F/A-18s.

"The primary goal is to park the red air aircraft behind the blue air and the have the blue air jets communicate about where red air is and then how to operate as a formation to reverse on red air and kill them. Once a fight is complete, such that red air has been killed, we want them to be able to get back together as a fighting formation and exit that area, or separate, as quickly as possible. It's regaining two-ship visual mutual support, what we call Blue 39. We want that to be a driving factor so in the future they are never going to leave a wingman alone. It's foundational for the rest of their air-to-air training.

"In this phase we want to keep the red air aircraft close by, so they don't enter into to a beyond visual range engagement. We need them to learn how to deconflict from their flight lead, how to communicate across the formation, how to make sure that they're shooting at the red air aircraft and not a blue air jet. We also need to reinforce the use of all three dimensions so they don't just focus on what they can do laterally, but keep in mind other dimensions, be it through G, time, space, and energy to operate a powerful F-15."

Basic Surface Attack

"At the start of the basic surface attack phase they've learned to work together as a crew, and how to work together as a formation. Now we teach them the basics of the air-to-ground mission set which represents 80% of what the F-15E is tasked to undertake. We also introduce low altitude operations and train them on a baseline selection of weapons at the beginning of this phase. Specifically, the 500lb GBU-12 laser-guided bomb, the 500lb GBU-38 and the 2,000lb GBU-31 GPS-guided JDAMs.

"The first two sorties are flown at medium altitude teaching the crew how to employ GPS or laser-guided munitions and how to do so as a formation. Because F-15E crews have to think about both offensive and defensive mission sets, we also start to train basic threat reactions, those used against older surface-to-air and man portable systems, so they learn how the jet performs at medium altitude.

"The next two sorties are flown to a weapons range where the crew uses the same employment functions as medium altitude, but now at low-level. The two sorties also introduce strafing. Three further sorties involve low altitude step down training, the first down to 1,000 feet, then down to 500 feet as a single ship, then down to 500ft as a formation, including tactical intercepts against another aircraft. During this phase, our focus is getting them to understand the feel of the aircraft and how to work together as a crew and as a formation at low altitudes."

Advanced Air Combat Manoeuvring

"This phase returns to the air-to-air role because crews need to keep that as part of their mindset. We're trying to train them in multi-role operations. There's flexibility inherent in the aircraft, and we want them to keep thinking about one thing and then the other not least because this phase leads into surface attack tactics, and the capstone events. To succeed in both they need to learn how to combine employing the F-15 in an air-to-air scenario with an air-to-ground scenario. This five-sortie phase furthers the knowledge of employing the aircraft, learning how to fight against another formation and transition to the visual range kill should special instructions and requirements dictate. Typically, two blue air versus two red air aircraft.

"They also learn how to respond defensively in an air-to-air scenario. Because we include tactics in a beyond visual range scenario with the understanding that a red air aircraft is going to cut loose from the fight, they have to be able to identify the red air aircraft that's still alive, where they're going in the airspace, change the geometry of their flight, talk between the formation, with one of them defending while the other is cleaning up the red air aircraft still at large. Then we set up the next engagement.

"Three further sorties involve tactical intercepts within a beyond visual range scenario with two blue air versus a minimum of two, but ideally four red air aircraft. This allows us to paint different pictures and different geometric considerations for their intercepts. By the end of the ACM phase, provided everything has gone well, they should achieve the majority of their air-to-air kills and solve the tactical problems given to them."

Advanced Surface Attack

"In the advanced phase of surface attack, we want them to be familiar with using the Sniper targeting pod. This phase comprises three sorties. The first two are flown to a weapon range so they can gain weapons currency or unfinished weapons qualifications. On at least one of the two sorties, we load a minimum of eight 500lb bombs for heavy munition employment. Then we qualify them on the weapons mentioned earlier. We also train them to use the low altitude terrain following radar and employing weapons using that radar.

"The third sortie is a capstone event designed to drive home the necessity of good mission planning and involves multiple attacks in a variety of scenarios including close air support with Joint Terminal Attack Controllers."

F-15E Strike Eagle 87-0191 SJ marked with the red tail band of the 333rd Fighter Squadron breaks away from the air refuelling boom after uploading fuel. [illegible]

Surface Attack Tactics

"This two-sortie phase includes dynamic targeting which typically involves crews working with a dedicated command and control agency. This first sortie also introduces crews to maritime strike warfare and involves hunting for specific boats or targets along the Atlantic coast. The second sortie is dedicated to destruction of enemy air defences. It is designed to drive home the need to understand the types of threat they may face in an air-to-ground environment, and how to deal with such threats using the variety of weapons the crew can bring to bear.

"Crews complete the course with two capstone sorties. Each one is designed by the squadron's weapon officers and are based on the needs of operational squadrons at the time. Typically, these involve a scenario in which the crews have to employ the aircraft in both the air-to-air and the air-to-ground roles in the same sortie. They must mix the two roles and go through a phase-based approach of how to tactically win each scenario."

Crew Performance

The F-15E B-course presents all student pilots and WSOs with a highly-saturated learning environment. The author asked Lt Col Bott how students cope with the pressure?

Answering, he said: "The purpose of the course is to build stress on the crews who must demonstrate the flexibility of mind and intellectual curiosity required to understand that what they do today may not be what they do tomorrow, and that being prepared is key. In any week of the course a crew might learn about aspects of the air-to-ground role one day, while flying air-to-air sorties the following day, and during the same week take tests on systems they've yet to use in a jet. By the end of the course, the vast majority of them have figured out what they individually need to do to be successful in their day-to-day study habits, time management, and how to improve upon their areas of weakness.

"We help them in a number of ways. First, we speak with their families both at the beginning of the course and as the student approaches the difficult phases, to explain what's happening. We outline what the family needs to be prepared for at home and the ways they can get support from the 4th Fighter Wing, making sure they know we are here to help. Each student is assigned a mentor, one of our instructor pilots or WSOs who gets to know the student and guides them through the difficult phases. Also, we assign groups of four students to a flight commander, a senior instructor, typically a captain. Someone with the ability to control their schedule and organise meetings with any of the squadron's staff to help with their needs.

"On average, about 15% of student crews would struggle to make it through the course if these measures were not in place. For those that are struggling, we put them on special monitoring status, and then only fly them with the most capable and senior instructors. We also organise their schedule with necessary study time built in and provide extra help to get them across the line. Today we're averaging a loss of one to two aviators per class usually due to a short fall in aptitude to the course. When that happens, they are reclassed into a different aircraft.

"Those that graduate attend a ceremony on a Friday and by Monday morning they'll start duty at one of the two operational squadrons based at Seymour Johnson to start three months of mission qualification training, which is an introduction to the different mission sets flown by their squadron.

TOP: ***In close formation with the KC-135 Stratotanker before aerial refuelling.*** *Ohio Air National Guard/Airman 1st Class Tiffany Emery*

ABOVE: ***Two F-15E Strike Eagles assigned to the 333rd Fighter Squadron fly alongside a KC-135 Stratotanker awaiting their turn to join on the boom.*** *Ohio Air National Guard/Airman 1st Class Tiffany Emery*

LEFT: ***A load crew member from the 333rd Aircraft Maintenance Unit prepares to load a GBU-31 JDAM onto an F-15E Strike Eagle.*** *US Air Force/Airman Kimberly Barrera*

LEFT: ***Airmen assigned to the 4th Munitions Squadron assemble a GBU-31 JDAM at Seymour Johnson Air Force Base, North Carolina. The three man crew is responsible for ensuring the munition is safe, serviceable, and properly configured.*** *US Air Force/Airman Kimberly Barrera*

BELOW: *F-15E Strike Eagle 89-0472/SJ assigned to the 333rd Fighter Squadron at configured with a standard training fit comprising an inert AIM-9 Sidewinder missile and a range instrumentation pod. US Air Force/Airman Kimberly Barrera*

BOTTOM: *An F-15E Strike Eagle assigned to the 333rd Fighter Squadron marked with tail markings for the 307th Fighter Squadron, an Air Force Reserve Command associate unit based at Seymour Johnson Air Force Base. US Air Force/Jacob Derry*

Those posted to Mountain Home or Lakenheath face a two or three week break in training to move and get checked in."

Changes

Over the last year the US Air Force has begun partnerships with industry and academia to design data analytical tools to be used for managing flying training courses, and thereby increase the number of favourable outcomes of training events for the students involved. This objective was achieved by adopting better records management, by having a better understanding of each student's performance up until the point they joined the 333rd FS, and by using statistical and data analytical modelling.

Lt Col Bott explained: "We've created a way of tracking how a student is performing and bettering their performance. We can see what their weak areas are, and then allocate the appropriate resources to help them. The course now uses courseware that any student can access on their cell phone instead of having to be at work to get access. Traditionally, when a student pilot conducted their first aerial refuelling with a tanker, they would fly the sortie with an instructor pilot in the backseat. Now the vast majority of student pilots fly to the tanker for the first time with an instructor WSO in the backseat, and for their second time usually with another student.

"They're able to do that thanks to the use of VR technology that allows them to practice in an immersive environment either at home or at work. The VR technology perfectly presents all of the motions encountered between their F-15E and a tanker aircraft during aerial refuelling. Typically, we sent 25% to 30% of student pilots up a second time with an instructor pilot because their performance was not good enough to safely conduct aerial refuelling.

With the advent of VR technology, in the past year no student pilot has required a second flight to the tanker with an instructor pilot in the backseat because they demonstrated their proficiency on their very first time to a tanker."

Command

One interesting aspect of the F-15E Strike Eagle training system is its command authority. Unlike the F-16 and F-35, which each have Air Education and Training Command fighter wings dedicated to training, the F-15E FTUs are part of Air Combat Command (ACC). Of the Air Force's 12 core functions, the majority reside with ACC, so the F-15E FTUs are purposely assigned to the command to specifically address some of those core functions.

The 333rd and 334th Fighter Squadrons are two of only a handful of FTUs within ACC, others reside at Davis-Monthan Air Force Base, Arizona for the A-10, and Tyndall Air Force Base, Florida for the F-22.

Each F-15E FTU is budgeted for a 5,700-hour flying programme per year. The 333rd FS is tasked to train approximately 107 students in the current FY2021, 48 of which are brand new to the Strike Eagle. Those 48 students take the preponderance of the training requirement because they each take much longer to train. Additionally, the 333rd and 334th both train 20 instructors a year and manage transition courses for officers returning to the F-15E after a desk job or those that come from another fighter type. Currently, the two F-15E FTUs are tasked with training 48 crews (96 officers) a year, a slightly higher number than in recent years to address the fighter pilot shortage faced by the US Air Force over the past five years.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PANTHERS

Mark Ayton reports on the latest operations flown by the F-15E-equipped 494th Fighter Squadron based at RAF Lakenheath, England

MAIN PHOTO: ***F-15E Strike Eagles assigned to the 494th Fighter Squadron, refuel from a KC-135 Stratotanker.*** *US Air Force/ SSgt Bethany La Ville*

Since mid-January 1960, RAF Lakenheath has been the home station of the US Air Force's 494th Fighter Squadron – the 'Panthers'. Back then, the unit was equipped with the F-100D Super Sabre and designated the 494th Tactical Fighter Squadron, a component of the 48th Tactical Fighter Wing. F-100D operations continued until February 1972. The squadron became and remained inactive until 1974 when it started to re-equip with the F-4D Phantom. Initial operational capability was declared with the F-4D in March 1975. Its tenure with the F-4D was a short three-year term after which it was assigned the F-111F Aardvark, its mount for 15 years. On November 30, 1991, redesignation to the 494th Fighter Squadron took effect under the US Air Force directive for Tactical Fighter Wings to restructure under the Objective Wing programme, which included dropping Tactical from unit titles. In 1992 the Panthers re-equipped with the multi-role F-15E Strike Eagle which it continues to fly making it the squadron's longest assigned jet.

Like all of the 48th Fighter Wing's flying squadrons, the 494th conducts temporary duty deployments around the US Air Forces in the European theatre and a high operational tempo of flight operations at Lakenheath. With over 300 airmen and over 20 F-15Es assigned

LEFT: ***F-15E 91-0604/LN assigned to the 494th Fighter Squadron uploads fuel from a KC-135 Stratotanker.*** *US Air Force/ SSgt Bethany La Ville*

BELOW: ***The WSO's view from the aft cockpit of the KC-135R Stratotanker and its aerial refuelling boom, as the F-15E closes on the probe to the left side of the Strike Eagle.*** *US Air Force/ SSgt Bethany La Ville*

the 494th Fighter Squadron has already accomplished some notable events in 2021 to date. The author spoke with the squadron's commander, Lieutenant Colonel Jonathon Hutto about recent accomplishments.

Immediate Response

In October 2019, the 494th was deployed for the first time as part of the Department of Defense's new Immediate Response Force doctrine, which requires individual units to deploy worldwide within 18 hours of notification. Destination was Al Dhafra Air Base in the United Arab Emirates. At the time, Lt Col Hutto was the new director of operations for the 494th who said sorties were flown in support of Operation Inherent Resolve over Iraq and Syria to counter ISIS forces and the increased aggression undertaken by Iran in the Gulf region during late 2019 and early 2020. Explaining the squadron's operational tempo, Hutto said: "At that time we were flying eight hour sorties, which makes for a 14-hour day. We flew every other day based on the number of people we had. On the days that you're not flying you're typically doing a ground duty, whether that's running the operations desk, the schedule, or the mission planning cell. It's a pretty busy life."

When a US drone strike killed Iranian Islamic Revolutionary Guard Corps General Soleimani near Baghdad International Airport on January 3, 2020, the assassination predictably changed the political fervour in both Iran and Iraq. Given Iran's capability to launch missile strike on targets in the United Arab Emirates, the US Central Command directed the 494th to relocate to Prince Sultan Air Base, Saudi Arabia: the base from where the first combat F-15E missions were flown during Operation Desert Storm.

Discussing the relocation with the author as the current commander, Lt Col Hutto said: "We packed up shop in six days. When we got to PSAB, it was bare. We were counting the equipment as it was coming in on the transport aircraft. The bombs we had on the jets were the bombs we had because at that point we didn't have the parts and components to assemble another one. Despite the initial conditions, we were the first US Air Force fighter squadron to launched from PSAB in over 15 years. We were all prepared to do what we could, whether it was defend the Gulf Coalition countries, provide presence, or counter-attack, but thankfully nothing happened, which was a good thing.

"We then started working with the Royal Saudi Air Force F-15 units based at Dharan and other squadrons that wanted to train with us. At the time Riyadh sustained some attacks launched from the south so the Royal Saudi Air Force was defending its airspace. We were on the end of a leash and didn't know when we would come home until the secretary of defense signed an order to re-deploy us home on March 1. It was glorious to see our families back at Lakenheath.

COVID

After two-weeks of reconstitution leave for the 494th, COVID-19 hit. The 492nd was preparing to deploy but the plan was postponed. Lieutenant Colonel Hutto took up the story: "We then had to figure out how to manage people, split shifts, and all aspects of squadron personnel's work when flying jets. The Air Force quickly offered a vaccine roll out through our medical programme for our primary people that are classed as Tier 1 Alpha. Medical personnel, first responders and those that deploy for national defence. The Strike Eagle falls in that category specifically because we carry a standby nuclear mission. Pilots and WSOs were offered vaccines quickly but it's on a volunteer basis. Most of our personnel got it. The only ones that didn't, had recently had Covid, and were probably immune anyway and opted to give their shot to somebody that needed it.

ABOVE: ***F-15E 91-0604/LN in close formation with another Strike Eagle.*** *US Air Force/SSgt Bethany La Ville*

ABOVE: ***An F-15E Strike Eagle assigned to the 494th Fighter Squadron stands inside the hush house before engine testing. A hush house minimises noise and provides a safe area for maintainers to run and inspect engines.*** *US Air Force/Senior Airman Madeline Herzog*

"At first, life on the squadron was very strange. We split the squadron in half and designated half the squadron, aircrew, and maintenance, as the red team and half as the black team, our squadron colours. Each team flew either the first wave or second wave of flying. Aircrews came into work and only mixed with the formation they were flying with, everybody masked, everybody sanitised and were wiping everything before flying their mission. With two crew members breathing the same air in the jet they had to trust each other, a situation that became more comfortable as the squadron did not experience any Covid breakouts.

"Eventually we had to start to mix the red and black teams to increase the effectiveness of the scheduling and get back to a cohesive unit, because sooner or later something's going to change. Nowadays, we're so used to each other and so comfortable in our own little bubble, we've accepted a little bit of risk around each other because we know we're safe back home.

"Restrictions continue such that many events are done virtually between the squadrons, even though both Strike Eagle squadrons are based in the same building so crossover is limited as much as possible.

"On the flight line, at first especially, pilots did not interact with maintenance at all. The crew chief put the aircraft's forms on the stand, the pilot gave a salute to say hello, looked at the forms wearing gloves, looked around the jet, climbed in holding their flight bag and buckled in for the flight. Each jet was thoroughly wiped down between flights. Nowadays, we still only interact with the maintainers at the jet, but we've started debriefing maintenance on the condition of the jet in an office with everybody masked and everything wiped down, so that's a separate bubble as well.

"In the early days of running a split maintenance team, things were tough because each team had just half the number of people with which to support the flight schedule. For the last nine months it's working back at the normal rate. On the occasions when one person got Covid we placed a lot of people in isolation to halt the spread. There was one instance when maintenance was shut down on a Friday, so we took the jets to Mildenhall and aircrew were marshalling them, chocking them, fuelling them, servicing the hydraulic fluids and oil, and putting air in the tyres to turn the jets.

Flight Ops During Covid

In any given year, the Lakenheath-based squadrons participate in numerous exercises and undertake temporary duty at different locations. Once Covid hit, the 494th completed one temporary duty to Aviano Air Base during the summer for a high-priority exercise. Otherwise, the three Lakenheath squadrons staged multiple large force exercises in the ranges over the North Sea which also involved RAF Typhoons, UK F-35Bs and F-16s and F-35As from the Royal Netherlands Air Force.

"We really narrowed down indigenously-generated high end training which became our focus

RIGHT: ***An F-15E engine running in afterburner inside the hush house at RAF Lakenheath. Aerospace propulsion technicians test and verify every engine to ensure its combat performance.*** *US Air Force/Senior Airman Madeline Herzog*

LEFT: ***An F-15E Strike Eagle loaded with extra munitions, including GBU-32 JDAMs and GBU-39 Small Diameter Bombs, prior to a ferry flight to Al Dhafra Air Base in the United Arab Emirates.*** *US Air Force/TSgt Paul Duquette*

as a means to maintain full mission readiness. And we participated in some exercises in which we did not have to land away, two in the Baltics and air policing in Iceland," said Lt Col Hutto.

More recently, the 494th has undertaken overseas detachments in accordance with the agile combat employment concept, one to Norway and one to Amari Air Base, Estonia. The F-15Es deployed with aerial refuelling support provided by KC-135R Stratotanker aircraft and a small maintenance team working within their own bubble at each base for up to a week. The jets landed, got refuelled and serviced by the maintenance team and launched for a second sortie the following day before returning to Lakenheath. The 494th had practiced the agile combat employment concept during exercise Max 2020 when aircraft landed at RAF Coningsby where a small maintenance team turned the jets between sorties.

The 494th first started training to the ACE concept while deployed to PSAB by conducting integrated combat turns, which involve fuelling the jet and loading missiles or munitions on to the aircraft between landing and the next take off. This included pilots learning how to turn the jet under combat conditions as a means of practicing what's required in the event of a landing at a random location without any help.

In early March, the 494th fired four AIM-120B AMRAAM air-to-air missiles over the Atlantic Ocean within the Hebrides Range Complex. This was followed by use of the Aberporth range in Wales where some of the squadron's youngest pilots dropped GBU-12 laser-guided bombs and GBU-31 JDAMs on target barges and shot some AIM-9 Sidewinder missiles at a towed target. The COVID-19 pandemic hampered the squadron's opportunity to deploy to Tyndall Air Force Base, Florida to attend Air Combat Command's Combat Archer (air-to-air) and Combat Hammer (air-to-ground) Weapon System Evaluation Programs. The programme provides aircrew with the opportunity to employ air-to-air missiles and drop munitions.

BELOW: ***F-15E 91-0311/LN assigned to the 494th Fighter Squadron takes off in afterburner at RAF Lakenheath, England.*** *US Air Force/Senior Airman Madeline Herzog*

Current Deployment

In April, the 494th started its latest standard rotational force deployment to an air base in the eastern part of the US Central Command theatre.

Lt Col Hutto described the squadron's operational tempo at the deployed location as standard involving a mix of partner nation integration sorties and training for contingency response missions. He said: "This involves operating around the theatre in accordance with the ACE concept, responding to events that might pop-up. We take a small detachment, maybe a quarter of the unit, because the rest is

LEFT: ***On April 25, 2021, the 332nd Air Expeditionary Wing loaded six 494th Fighter Squadron F-15Es with extra munitions, including BLU-129/B Laser-guided JDAMs, GBU-32 JDAMs and GBU-39 Small Diameter Bombs, for a ferry flight to Al Dhafra Air Base in the United Arab Emirates.*** *US Air Force/TSgt Paul Duquette*

ABOVE: *US Air Force/ Senior Airman Madeline Herzog*

focussed on Iraq and Syria, to countries on the Arabian Peninsula for exercises. Activity ebbs and flows depending on the day. In the next 24 hours, you just don't know if it's going to be high end full spectrum combat operations or a training sortie fighting with a partner nation squadron. It could be figured out on the fly and definitely makes you think on your toes. We tell our aircrews, don't expect what you see on the schedule to be reality. Just show up, be professional and flow with the punches."

On April 25, the 494th deployed six F-15Es to Al Dhafra Air Base in the United Arab Emirates in accordance with the ACE concept. Each aircraft was loaded with a tactical ferry munitions load-out, double the standard munitions load, and was the F-15E's first such combat tactical ferry mission.

On February 22, Air Combat Command's F-15 operational test unit, the 85th Test and Evaluation Squadron based at Eglin Air Force Base, Florida, flew an F-15E loaded with six JDAMs on one sortie to demonstrate the initial tac-ferry proof of concept within the ACE concept.

Explaining the April 25 deployment, Lieutenant Colonel Curtis Culver, 494th Fighter Squadron director of operations said: "The six F-15Es are carrying what is called a 'tac-ferry' load out. That means we can manoeuvre using Agile Combat Employment and be postured to go forward from a main operating base. This is the next step for the Air Force in Agile Combat Employment. So, instead of having multi-capable airmen that are exercising manoeuvre and logistics, now we're doing that with sustained munitions to project power."

Captain Jessica Niswonger, 494th Fighter Squadron weapon system officer and mission planner said: "We were asked to support combat missions with a very short turnaround, and with bombs not previously built here for us. By carrying more bombs than we'd actually carry to drop, we're setting up for the initial days of combat."

As part of the ACE detachment to Al Dhafra, the 494th FS immediately commenced flying sorties to meet air tasking orders issued by US Central Command.

Aircraft Availability

Given the age, flight hours accumulated, and the utilisation rate of F-15Es throughout the US Air Force fleet, keeping the jets mission ready is hard work for the maintenance squadrons.

Lt Col Hutto was full of gratitude for his maintenance troops: "They make miracles happen with what they have. They work hard, and they do very well at it. I never have a doubt that my assigned jet is not safe to fly or in pristine condition. They work 12-hour days, every day, but it wears on them after time, especially if they need a part which will takes two weeks to arrive on the squadron.

BELOW: ***F-15E Strike Eagles assigned to the 494th Fighter Squadron parked on the flight line at Łask Air Base, Poland, April 22, 2021 during ACE exercise Agile Liberty.*** *US Air Force/Senior Airman Madeline Herzog*

"The Strike Eagle is such a versatile platform, able to do air-to-air and air-to-ground, and because it operates with a two-person crew, both can share duties when the workload is high. That's one reason why the F-15E is such a high demand asset, and with just six operational squadrons throughout the Air Force, we're pretty loaded."

Commander's View

Describing how the F-15E is to fly, Lt Col Hutto said: "It's everything you want, it's more than you can handle, and you can overfill your bucket very quickly. It's simple to fly once you get used to it. It's really just the tactics of it that can be challenging. You are asked to do so much with the jet that you've got to know the systems and how the weapons work, in and out.

"If you're conducting just air-to-air, wall-to-wall, then you're slick, you're light, you can get fast, you can get high, you can really rage it, and it can black you out if you want. Or as soon as you strap on an extra ten tons of air-to-ground payload, wow, you can be underpowered pretty quickly if you don't watch it, so you've got to keep the speed on the jet. With 29,000lb of thrust pushing out per side if you select max afterburner, you can get back to fighting speed pretty quickly. But if you're trying to save gas you can get yourself in a pinch pretty quickly.

"We pretty much always carry a baseline load out of air-to-air and air-to-ground weapons, any flavour of ordnance that the ground force commander or the strategic targeting cell needs to destroy the intended targets; a mix of 250lb and 500lb munitions. Also, the gun's always hot, so if I get into a knife fight in a phone booth with somebody else, then a single one button fires the gun."

The author finished his discussion with Lt Col Hutto by asking about the advantage of being based at Lakenheath and the endless training opportunities afforded by its location close to the ranges and proximity to other fighter squadrons from neighbouring NATO nations with highly capable pilots and aircraft. Hutto replied: "It's dynamic, the ops tempo is high, and you could be operating anywhere in Europe tomorrow. It keeps it exciting. Qualitatively, I think Lakenheath crew make the best flight leads, with the ability to think dynamically. Whether it's dealing with other countries or other platforms, or just dealing with the weather, our crews can do anything in the dynamic environment. The highlight of our strength is our people throughout the squadron."

LEFT: ***Aircrew assigned to the 494th Fighter Squadron step through the heritage arch on their way to the flight line.*** *US Air Force/ Airman Jessi Monte*

BELOW: ***A crew chief assigned to the 494th Aircraft Maintenance Unit scrapes frost off the canopy of an F-15E Strike Eagle during a winter's morning at RAF Lakenheath.*** *US Air Force/Senior Airman Madeline Herzog*

"The F-15E is everything you want, it's more than you can handle, and you can overfill your bucket very quickly."

Lieutenant Colonel Jonathon Hutto, Commander 494th Fighter Squadron